This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.

+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.

+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.

+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

GODFREY LOWELL CABOT SCIENCE LIBRARY
of the Harvard College Library

This book is
FRAGILE
and circulates only with permission.
Please handle with care
and consult a staff member
before photocopying.

Thanks for your help in preserving
Harvard's library collections.

C

COMMUNICATIONS AND REPORTS

IN RELATION TO THE

SURVEYS OF BOSTON HARBOR

BY THE

UNITED STATES COMMISSIONERS,

JOSEPH G. TOTTEN,

Brevet Brigadier-General United States Army, Chief Engineer,

A. D. BACHE,

Superintendent United States Coast Survey,

C. H. DAVIS,

Commander United States Navy,

DETAILED FOR THAT PURPOSE BY THE UNITED STATES
GOVERNMENT, AT THE REQUEST OF THE CITY
COUNCIL OF BOSTON, 1859.

BOSTON:
J. E. FARWELL & CO., CITY PRINTERS,
No. 32 Congress Street.
1862.

Eng 1015.62

HARVARD COLLEGE
Feb 19, 1925
LIBRARY

W. Sumner Appleton

[illegible] form

INDEX.

The Mayor's Communication, October 24, 1859. — City Document, No. 64.

Communication from the Commissioners in relation to the Waters of Mystic River and Pond, March 20, 1860. — City Document, No. 34, 1860.

Preliminary Report of the Commissioners, March 29, 1860. — City Document, No. 37, 1860.

Report of the Committee on the Survey of the Inner Harbor, November 12, 1860. — City Document, No. 88.

Second Report of the Commissioners on the Condition of Boston Harbor, December 24, 1860. — City Document, No. 97.

Special Report on the relation of Mystic Pond and River to Boston Harbor, December 18, 1860. — City Document, No. 12, 1861.

Fourth Report of the Commissioners on Boston Harbor, September 28, 1861. — City Document. No. 62.

Fifth Report of the Commissioners on Boston Harbor, September 28, 1861. — City Document, No. 63.

City Document.—No. 64.

CITY OF BOSTON.

THE MAYOR'S COMMUNICATION

IN RELATION TO A

SCIENTIFIC SURVEY

OF

BOSTON HARBOR.

1859.

CITY OF BOSTON.

Mayor's Office, City Hall,
Boston, Oct. 24, 1859.

To the Honorable City Council:

One of the most important subjects demanding your earnest solicitude as the guardians of the interests of the city, is the present condition and prospects of Boston Harbor. The prosperity of our city is intimately connected with its foreign and coastwise commerce. Its situation on the Atlantic seaboard, having one of the best harbors in the world, has given it its rank as one of the most important maritime ports of modern times. Anything which endangers the safety of its Harbor caused either by the hand of man or the ravages of the sea, should be watched with jealous scrutiny and care.

Its local importance to ourselves, as well as to the Commonwealth, of which we are the capital, cannot be over-estimated, but it has a national importance equally significant, for within its waters is established one of the best of the naval stations of the Union, and through its Custom House a large portion of the revenues for the support of Government are collected. Boston Harbor does not belong to Boston alone, but to the whole nation; and we are recreant to duty, if, living in the immediate vicinity, we do not adopt all those instrumentalities which shall secure its safety.

The subject has often attracted the attention of the City Government, and of the Legislature, and several commissions have been appointed for its consideration. Their action, however, has been confined principally to the upper Harbor, which is more particularly under the local jurisdiction of the State and City. Recent investigations have shown that the time has come for some energetic measures, which shall embrace the lower as well as the upper Harbor. In the former, islands and headlands are washing away; the ship-channel is becoming narrow, and symptoms are every day developing, the results of which will be disastrous, if not speedily checked and abated.

The National Government has done much, by the strength and character of its fortifications, to assure our safety from the attack of the foreign fleets of an enemy, but their attention should now be solicited to those insidious assaults of the sea, which are constantly undermining and putting in jeopardy the integrity of the Harbor.

Through the exertions of one of our late Representatives in Congress, Mr. Comins, a bill was reported at the last session, from the Committee on Commerce, making an appropriation for a scientific survey. The bill failed to pass the House, not so much, I understand, from an indisposition to aid the matter, as from a want of knowledge of the facts which would justify such an appropriation. In this dilemma, following the example of other cities, I would suggest for your consideration the appointment of a Commission for the examination of the subject. These Commissioners should be men of high scientific attainments, of much experience in the examination of tidal waters and oceanic currents, free from any local bias, and whose testimony would be of weight in the Congress of the United States. Some tangible facts from a source which cannot be questioned, must have an influence upon that body.

I would further suggest for this Commission the names of Gen. Totten, Chief Engineer of the United States, Prof. Bache, Superintendent of the Coast Survey, and Commander C. H. Davis, of the United States Navy. These three gentlemen seem to meet all the requirements for such an important and delicate duty, and I have no doubt, from their interest in their profession, and the enlightened public spirit which they have evinced in other works of this nature, they would cheerfully undertake the task if you honored them by the appointment.

A Commission thus constituted would be of but little pecuniary expense to the city. These gentlemen are already in the service of the United States, and I am confident that the Executive Department would readily detail them for this duty if your wishes were known in this matter.

I would suggest an immediate attention to this subject. The surveying steamer "Bibb," is already in our Harbor, and Lieut. Commandant Murray is engaged, under the orders of the Superintendent of the Coast Survey, in making some important explorations. These investigations, together with previous surveys, can be made the groundwork of the Commission if they should enter upon this duty.

If the Commission is organized now, it would much facilitate the work, as it probably might be finished during the next summer.

The subject is of vital importance, not only to the interests of navigation, but to all other interests affecting the commercial prosperity of our city, and I respectfully bring it to your consideration.

F. W. LINCOLN, Jr., *Mayor.*

In Board of Aldermen, Oct. 24, 1859.

Referred to the Committee on the Harbor. Sent down for concurrence.

SILAS PEIRCE, *Chairman.*

In Common Council, Oct. 27, 1859.

Concurred.

J. P. BRADLEE, *President.*

CITY OF BOSTON.

In Board of Aldermen, Oct. 31, 1859.

The Joint Standing Committee on the Harbor, to whom was referred the communication of His Honor the Mayor, of the 24th instant, have duly considered the same, and respectfully

REPORT

That they are fully conscious of the great importance of a resurvey of our Harbor, especially in those parts which are most exposed to the action of the currents, and where the earth is washed from the islands and headlands and is deposited, to th obstruction of vessels entering and leaving this port.

Many members of the present City Council are aware that early in the month of February, 1858, an invitation was extended to our Senators and Representatives, and to many of the scientific and professional men of the city, to accompany the City Government down the Harbor, for the purpose of visiting the places then most dangerous to navigation. All who were present at that time were of opinion that the General Government ought to take immediate and decided steps to remove the existing dangers. His Honor the Mayor conferred with our Representatives in Congress upon the subject, and they took active measures to induce the General Government to undertake a more effectual protection to the Harbor.

Early in the present year, an order was introduced in the City Council, and referred to the Committee on the Harbor, instructing that Committee to consider and report what improvements can be made in the Harbor for the benefit of the shipping interests of the city. Upon that order the Committee have delayed making any report, for the reason that gentlemen of high scientific attainments, with whom they were in correspondence, were unwilling that the attention of Congress should be particularly directed to the subject, except with a view to an accurate and complete re-survey of the Harbor..

The Committee deem it of the most vital importance that the General Government should at once sanction the appointment of a Commission to make a survey, and should also take measures to check the disastrous inroads of the currents which are now destroying the headlands and islands, and making the channel dangerous to vessels of deep draught. If such measures are not speedily undertaken, vessels of large size will be debarred from entering our Harbor at all. And in this aspect the subject is of no less importance to the navy than to the nercantile community.

The Committee most cordially acquiesce in the views and suggestions of His Honor the Mayor; and in according to him their thanks for the assiduous and zealous interest he has manifested in respect to this matter, they feel that they only give voice to the general sentiment of the commercial community whose prosperity so much depends on the preservation of our Harbor as a safe and accessible port. But the Committee do not deem it necessary to enter upon any argument regarding a subject which is so well understood already by the City Council; nor do they propose to make any more particular statement of the necessities for prompt action, believing that it will come more fully and accurately from the Commission for which a desire has been expressed.

With these views, the Committee respectfully request the passage of the accompanying orders.

For the Committee,

JESSE HOLBROOK, *Chairman.*

Ordered, That His Honor the Mayor and the Committee on the Harbor be authorized to invite, in behalf of the city, Gen. Totten, Chief Engineer of the United States, Professor Bache, Superintendent of the Coast Survey, and Commander C. H. Davis, of the United States Navy, to act as Commissioners to investigate and report upon the condition of Boston Harbor, with a view to its preservation and safety for the interests of navigation, and that they be further authorized, if they obtain the consent of these gentlemen to act in this capacity, to solicit the Executive Department at Washington to detail said Commissioners for this special service, if it should not interfer with their official obligations to the United States Government.

Ordered, That the Committee on the Harbor be authorized to take such further measures as they may deem expedient in regard to the matter, the expenses of the same to be charged to the appropriation for the Harbor.

In Board of Aldermen, October 31, 1859.
Read twice and passed. Sent down for concurrence.
SILAS PEIRCE, *Chairman.*

In Common Council, November 3, 1859.
Concurred.
J. P. BRADLEE, *President.*

Approved November 5, 1859.
F. W. LINCOLN, Jr., *Mayor.*

City Document.—No. 34.

CITY OF BOSTON.

COMMUNICATION

FROM THE

COMMISSIONERS ON BOSTON HARBOR

IN RELATION TO THE

WATERS OF MYSTIC RIVER AND POND.

1860.

REPORT.

WASHINGTON, D. C.,
March 20, 1860.

HIS HONOR F. W. LINCOLN, JR., *Mayor of Boston,* and JESSE HOLBROOK, ESQ., *Chairman Harbor Committee.*

GENTLEMEN: I have the honor to transmit to you the report of the Commissioners, in reply to the order of the Board of Aldermen of January 23, 1860.

Very respectfully,
Your obd't servant,

JOS. G. TOTTEN,
Bt. Brg. Gen. Top. Eng.

We, the undersigned Commissioners, appointed by the General Government, at the request of the City Government of Boston, for the purpose of examining Boston Harbor, and of furnishing information concerning it, have had the honor to receive your communication of January 24, 1860, transmitting an order of the City Government asking the opinion of the Commissioners upon the probable effect of certain proposed changes in the Mystic Pond and River.

A copy of this order is inserted here for convenient reference.

COPY.

CITY OF BOSTON.

In Board of Aldermen, January 23, 1860.

ORDERED: That His Honor the Mayor be requested to obtain from the Boston Harbor Commissioners an opinion upon the probable influence which would be exerted on Boston Harbor, if the changes contemplated by the City of Charlestown, in the disposition and level of the water in Mystic Pond, should be carried into operation.

Passed. Sent down for concurrence.

(Signed.) OTIS CLAPP, *Chairman.*

In Common Council, January 26, 1860.

Passed in concurrence.

(Signed.) J. P. BRADLEE, *President.*

Approved, Jan. 30, 1860.

(Signed.) F. W. LINCOLN, JR. *Mayor.*

A true copy. Attest:

(Signed.) S. F. McCLEARY, *City Clerk.*

We have also received copies of THE REPORT ON SUPPLYING THE CITY OF CHARLESTOWN WITH PURE WATER, from which we learn what influence the proposed changes are expected to exert upon the bed of the Mystic River.

We have, after mature deliberation, and a careful examination of the case, with such means as are in our hands, decided to make the general recommendation that no changes be made which will affect either the bed of the rivers emptying into Boston Harbor, or the reservoirs of the Harbor, until we have had opportunity for further investigation, and additional means for a more detailed report. We have not satisfactory information that the case of the Mystic River and Pond may be safely made an exception to this recommendation.

We have the honor to be,
Very respectfully,
Your obedient servants,

JOS. G. TOTTEN,
Bt. Brg. Gen. Top. Eng.

A. D. BACHE,
Sup't U. S. Coast Survey.

C. H. DAVIS,
Com'r U. S. N:, Supt. N. A.

WASHINGTON, D. C.,
March 20, 1860.

TO HIS HONOR F. W. LINCOLN, JR., *Mayor of Boston,* and JESSE HOLBROOK, ESQ., *Alderman, and Chairman of the Harbor Committee.*

City Document.—No. 37.

CITY OF BOSTON.

PRELIMINARY REPORT

OF THE

COMMISSIONERS ON BOSTON HARBOR.

1860.

REPORT.

WASHINGTON, D. C.,
March 29, 1860.

GENTLEMEN: I have the honor to transmit the preliminary report of the U. S. Commissioners on Boston Harbor.

Very respectfully,
Your obd't servant,
JOS. G. TOTTEN,
Bt. Brig. Gen. and Col. of Engineers.

TO HIS HONOR F. W. LINCOLN, JR., *Mayor of Boston*, and JESSE HOLBROOK, Esq., *Alderman, and Chairman of Harbor Committee.*

WASHINGTON, D. C.,
March 29, 1860.

GENTLEMEN: We, the undersigned, have had the honor to receive your communication of November 15, addressed to each one of us separately, transmitting a copy of City Document No. 64. By the authority conferred upon you by the latter, you have invited us to act as a Board of Commissioners for the examination of Boston Harbor.

In the communication of His Honor, the Mayor, to the Honorable City Council, the national importance of this harbor, within the waters of which "is established one of the best of the Naval stations of the Union," while, "through its

Custom-House, a large portion of the revenues for the support of the Government is collected," is justly dwelt upon. "Boston Harbor does not belong to Boston alone, but to the whole nation." This is true in the same sense of all the harbors of the Union. While, therefore, we signify our acceptance of the appointment, which you have done us the honor to offer, we take it as a public trust and duty, to which we find ourselves called by our official position.

Both of you, gentlemen, in your official communications and letter, have shown yourselves aware that changes are going on in the harbor of Boston, "from the encroachments of the sea, or, from other causes, which are seriously damaging its facilities for the purposes of navigation," — "destroying the headlands and islands, and making the channels dangerous to vessels of deep draught," — and that "the ship-channel is becoming narrow, and symptoms are every day developing, the results of which will be disastrous if not speedily checked and abated." You have here alluded in a distinct manner to some causes of deterioration which have long been in operation.

The changes they have produced have been too gradual to attract the attention of the casual observer; but they have not escaped the notice of those whose pursuits have led them to make Boston Harbor a constant study.

The injurious effect of these changes is most apparent in those parts of the harbor which have the least to spare in room, and are most easily impaired by slight deviations in the direction of the channel.

This is the case with that part of the main ship-channel between Gallop's and Lovell's islands, called the Narrows. The east end of Gallop's Island and the southwest extremity of Lovell's Island have increased so much, that these two points overlap each other to the view of one approaching the Narrows from the south.

Formerly, a vessel coming up from Nantasket Roads, round the south and west sides of George's Island, saw a clear expanse of water through the Narrows; at present, this is cut off. This increase of land involves such a change in the direction of the deep water, that a channel which was formerly nearly straight, and comparatively easy of passage, is now tortuous and difficult, and, therefore, more dangerous.

The east end of Gallop's Island has been robbed to such an extent of its loose shingle for ballast, that all the heavier surface material has been removed, leaving the lighter material subject to the ravages of the storms during high, and especially the highest (equinoctial) spring tides. It is this material which has built up the southeast part of the island, and encroached upon deep water to such an extent, that, where the pilot-boats at one time ran boldly up to a steep shore and landed their crews, or laid securely while reefing down in a gale, there is now shoal ground.

These and similar facts are noticed and mentioned by the oldest and most intelligent of the pilots, — Messrs. Wilson, Hunt, Gurney, Fowler, Alfred Nash, and others, who, it is to be remembered, are, in all that relates to sailing lines and marks, and to the navigation of the channels, not occasional and accidental witnesses, but experts, whose knowledge, well defined and rendered strictly accurate by ranges, cross bearings, and compass courses, lays claim to a scientific character.

Again, if we examine that part of the main ship-channel which lies in the inner harbor, between South Boston and Bird Island flats, by means of a comparison with former surveys, we shall find similar reasons for apprehension.

We have, very recently, collected the material for such a comparison, and we have contrasted the present condition of this reach of the main ship-channel with its condition in 1846 and in 1847. Our conclusions are, in general, that the navigable part of the inner harbor of Boston has lost in area; that the width of this channel is less; that the direction has been altered; and that the depth in the middle of the channel has not diminished.

We have selected these two portions of the main ship channel in the inner and outer harbors as the exponents and tests of alterations.

But we have abstained from anything more than is necessary to explain the course we intend to pursue hereafter. We are, indeed, not prepared to go further.

We propose, —

First. To make such hydrographical and topographical surveys as will supply us with the grounds for forming a correct judgment concerning the changes in Boston Harbor, and the tendencies of these changes.

Second. To investigate the causes of change.

Third. To endeavor to point out the remedial measures necessary to prevent further deterioration.

The first and second of these undertakings are the objects to which we shall direct our attention during the approaching summer and autumn. After having discussed them fully in frequent meetings held for the purpose of maturing our plans of proceeding, we adopted the following resolutions: —

Resolved, That the Superintendent of the Coast Survey is requested to furnish the Commissioners with an estimate of the cost of a new hydrographic survey of the main ship-channel of Boston Harbor; a topographical survey of the shores and islands of the lower harbor, north of the parallel of 42° 18′; and of gauging the Charles, Mystic, and Neponset rivers; specifying the cost under each head.

Resolved, That the Superintendent of the Coast Survey is requested to furnish the Commission with an estimate of the cost of a comparative map of Boston Harbor, exhibiting the lines of the various surveys from eighteen hundred and seventeen to the present time.

Resolved, That the Superintendent of the Coast Survey is requested to furnish the Commissioners with an estimate of the cost of a complete series of current observations in Boston Harbor.

In compliance with these resolutions, the Superintendent of the Coast Survey, submitted the following statement and estimates: —

1. The main ship-channel and its immediate dependences and connections.

Wherever the operations of the Coast Survey have been conducted in the usual manner, the points of primary, secondary, and tertiary triangulation are left in such a condition as to form the convenient basis of a new survey. The Coast Survey Office furnishes also, with facility, the projections for the working sheets of the plane table, and hydrographical parties. No estimate, therefore, will be necessary for the fundamental, and, by far the most costly, work of the examinations in view.

In most cases, also, the instruments and materials are collected and ready for use. They are not, with the exception of the case of current observations, included.

In the estimate for the water survey, it has not been thought expedient to ask for anything but coal, &c., and a pilot. The changes in the main ship-channel would, under any circumstances, demand the early attention of the Coast Survey; and with a suitable supply of coal, the requisite examination can be made soon, and without interruption.

The cost of the coal, counting sixty running days, at six tons a day, and six dollars a ton, will be, $2,160; to which is added the sum of $750, for pilot and contingencies; making a total of $2,910.

2. The Topographical Survey of the islands, etc.

It is apparent from the objects in view that a survey on the ordinary scale of one ten-thousandth, with the amount of detail belonging to that scale, would not be sufficient. The estimates have, therefore, been based upon the conclusion that the topographical work would be executed on a scale twice as large, which will enable the surveyor to furnish an exact map, embracing all that will be wanted in estimating the cost of public works designed for the protection of the island from the destructive action of the sea.

In forming an estimate of the time which this portion of the survey will occupy, the various islands and shores have been considered separately.

The whole number of working days required is about fifty, to which it is usual to add fifty per cent for bad weather; further allowance is to be made for travelling, for the organizing and removal of parties, and for accidental delays. It will be desirable to have the means of profiting to the utmost by all favorable circumstances of tide and weather; the services of a small vessel will, therefore, be essential.

The estimate of the cost of the topographical survey, based upon the preceding views, is as follows: —

Assistant, aid, 4 men, per month . . .	$300 00
Sailing-master and cook	100 00
Water and contingent expenses . . .	30 00
Per month	$430 00
Number of months . . .	3·5
	$1,505 00

3. Gauging rivers, and current observations.

These two operations are separated in the resolutions, but are brought together here, because they are included in the same estimate, and will be carried on simultaneously by the same party. The importance attached to this branch of the work is shown by the number of current stations selected. It is presumed that it is to this investigation we are chiefly to be indebted for our knowledge of the precise manner in which changes are brought about in certain cases, not now perfectly understood. The study of the actual causes and modes of physical change, so far as they are dependent upon the currents, must be slow and minute. It will probably extend through more than one season, and our previous experience has shown that observations of this character increase in number as they increase in importance, and that the labor to be bestowed upon them in the office is hardly less than that required in the field.

The estimate is divided into two parts, outfit and monthly expenditures.

The outfit, including transportation of party, apparatus, boats, and equipments, will amount to		$390 00
The monthly expenditures will be,		
For pay of persons employed, including aids, observers, seamen, cooks, boat-keepers, &c.,	$501 00	
Subsistence of all persons employed,	504 00	
		$1,005 00
Allowance is here made for two and a half months' work only, during the coming season. The estimated cost, under this head of outfit and monthly expenditures, will be		$2,902 50

FOURTH. COST OF COMPARATIVE MAP.

The Comparative Map of the inner harbor, on a scale of one ten-thousandth, compiled from the surveys of 1817–1846, will cost	$136 00	
That of a similar map of the outer harbor, showing the surveys of 1817 and 1846, will be	$157 00	
Total,		$293 00
If an additional survey is added to the outer harbor map, the increase in cost will be about		$50 00
The aggregate of the several estimates is		$7,610 50

We, the Commissioners, examined the preceding estimates of the Superintendent of the Coast Survey, which were presented to us in detail. We are satisfied of their economy and accuracy, and we take the liberty to invite you to bring the subject before the City Government, in time to enable us to set on foot our parties as soon as the weather will permit them to take the field with advantage.

We close this Report with two recommendations.

We recommend, in the first place, that prompt and effectual measures be taken to prevent the removal of any more material from Gallop's and the other islands of the harbor; and that the former be taken out of private hands, if possible, and put into public keeping.

And, in the second place, we recommend that the existing water area be preserved until some plans and some principles are recognized and adopted, by which private interests may be subserved without the sacrifice of the public good.

We have the honor to be

Very respectfully,
Your obedient servants,

JOS. G. TOTTEN,
Bt. Brig. Gen. and Col. of Engineers.
A. D. BACHE,
Supt. U. S. Coast Survey.
C. H. DAVIS,
Com'r. U. S. N., Supt. N. A.

To His Honor F. W. Lincoln, Jr., *Mayor of Boston*, and Jesse Holbrook, Esq., *Alderman and Chairman of the Harbor Committee.*

City Document.—No. 88.

CITY OF BOSTON.

REPORT OF THE COMMITTEE

ON THE

SURVEY OF THE INNER HARBOR.

1860.

CITY OF BOSTON.

BOSTON, MASS., *November* 2, 1860.

GENTLEMEN: In a letter dated August 31, 1860, the Harbor Commissioners asked authority to expend five hundred dollars ($ 500) in comparative maps of Boston Harbor; and I now have the honor to inform you that these maps are completed and ready for your examination. One of these is so shaded as to exhibit the changes in the inner harbor up to the year 1848. You will perceive that these changes are of a very striking and even alarming nature.

The Commissioners think it of the highest importance that a new survey of the inner harbor should be made, of the most minute and accurate description, in order that the comparison may be brought down to the present time; and I am instructed by my colleagues to bring this subject to your notice, and to ask your decision upon it before an adjournment, which will take place on Wednesday or Thursday next.

The survey we recommend will be a repetition of that made by the first Commissioners on Boston Harbor, Messrs. Baldwin, Thayer, and Hayward, which cost at that time, (1835–36,) the sum of six thousand dollars, ($ 6,000,) as we find by documents in the State Department of this State. The cost at the present time would, for obvious reasons, be somewhat greater.

The work contemplated in our first or preliminary report has been executed, and the results will be transmitted to you in a second report, before the close of the year.

Very respectfully yours,

JOSEPH G. TOTTEN.

His Honor F. W. LINCOLN, JR., Mayor of Boston, and JESSE HOLBROOK, ESQ., Aldermen, Chairman Harbor Committee, City Hall, Boston.

CITY OF BOSTON.

In Board of Aldermen, November 12, 1860.

The Committee on the Harbor have received the accompanying communication from the Commissioners on the Survey of Boston Harbor. It briefly states the result of a survey of the inner harbor, — that is, the portion above the Charlestown bridges, known as the Charles River, — made in 1848, which showed most remarkable and dangerous changes since the last previous survey. It is well known that several bridges have been thrown across the Charles River since 1848, and other obstructions to the full and free course of tides have been permitted. There is therefore every probability that the injuries caused to the channel and the tidal reservoirs in the inner harbor have been even more serious than during the interval between the two previous surveys.

The Committee concur with the Commissioners, that a new survey is highly important, and they recommend the passage of the accompanying order to accomplish the object.

For the Committee,
JESSE HOLBROOK, *Chairman.*

Ordered, That His Honor the Mayor and the Committee on the Harbor, be authorized to request, in behalf of the City, the Commissioners on the Survey of the Boston Harbor to make a further survey of the inner harbor of Boston; and that the Committee on the Harbor be authorized to take such further measures as they may deem expedient in relation thereto.

Ordered, That the sum of Eight Thousand Dollars be appropriated for the survey of the inner harbor of Boston, and that the Committee on Finance be requested to provide the means.

In Board of Aldermen, November 12, 1860.

Read twice and passed. Yeas, 9; Nays, none. Sent down for concurrence.

OTIS CLAPP, *Chairman.*

In Common Council, November 15, 1860.

Concurred. Yeas, 37; Nays, none.

J. P. BRADLEE, *President.*

Approved, November 17, 1860.

F. W. LINCOLN, Jr., *Mayor.*

City Document.—No. 97.

CITY OF BOSTON.

SECOND REPORT

OF

UNITED STATES COMMISSIONERS

ON THE

CONDITION OF BOSTON HARBOR.

1860.

In Board of Aldermen, Dec. 24, 1860.

Laid on the table, and one thousand copies ordered to be printed.

Attest:

S. F. McCLEARY, *City Clerk.*

The scale of the tracings appended to this report is $\frac{1}{5000}$

CITY OF BOSTON.

MAYOR'S OFFICE, CITY HALL,
BOSTON, *Dec.* 24, 1860.

To the Honorable City Council.

I have the satisfaction of transmitting to your honorable body the accompanying Report of the Commissioners on Boston Harbor. This is their second Report, embracing an account of their labors during the past season, with such recommendations as in their judgment they deem advisable to bring to your notice.

This enterprise was commenced for the purpose of ascertaining from competent authority the exact condition of the Harbor, and the changes now going on in it, with a view to such legislation by Congress, the Legislature, or the City, as will secure its preservation and safety. As the work has progressed, it has been found necessary, to make it thorough and complete, to go more into detail than was originally contemplated, thereby requiring more time for its prosecution. It is not yet finished, but will require another season to complete the undertaking. In the mean time the present Report is submitted, and as its specific recommendations are those connected with the Lower Harbor, which require the action of the National Congress, the Harbor Committee, in connection with myself, have felt it a duty to personally call upon our members of

Congress, and the Departments at Washington, to represent the exigency of the case, and to secure, if possible, their aid and co-operation in behalf of a liberal appropriation. We feel confident that when the present perilous crisis in our national affairs has passed, and Congress resumes its ordinary legislation, a grant will be obtained; for it is for an object which, although of considerable local importance to our City, is yet of equal importance to the United States.

Two additional special Reports from the Commissioners will be laid before you before the close of the present municipal year; one in answer to the inquiry of the City Council as to the effect upon the Harbor of the contemplated project of supplying the City of Charlestown with water from Mystic Pond; and the other in relation to the Eastern Avenue, so called,—which report, in addition to their opinion on that subject, will probably embrace a comprehensive plan for the occupation of the South Boston flats with Wet Docks and Basins, after the manner of the most important maritime ports of the old world.

I embrace the opportunity which this communication affords, to acknowledge with gratitude the eminent services of the distinguished gentlemen who constitute this Commission. The elaborate document which is now laid before you is an evidence of great labor and industry, and when it is considered that their time and skill are proffered without any hope of pecuniary reward to themselves, it is an example of public spirit which cannot be too highly commended.

F. W. LINCOLN, Jr., *Mayor.*

REPORT.

Washington, D. C., *Dec.* 12, 1860.

Gentlemen:

In our preliminary Report of the 29th of March of this year, after calling your attention to the changes which had taken place in two important parts of Boston Harbor, viz. the *Narrows*, and the navigable part of the inner harbor, we submitted to you a proposition to make such hydrographical and topographical surveys as would supply us with the means of forming a correct judgment of the nature of these changes, and of their tendencies and remedies.

These surveys were embraced under three principal heads. A hydrographic survey of the main ship channel; a topographical survey of the shores and islands of the lower harbor, north of the parallel of 42° 18′ of latitude; and gauging rivers, and current observations.

The first two of these surveys have been completed in the manner originally designed. The third has progressed as rapidly and favorably as was expected. Of this survey we said in our Report: "It will probably extend through more than one season, and our previous experience has shown that observations of this character increase in number as they increase in importance, and that the labor to be bestowed upon them in the office is hardly less than that required in the field." Our anticipations in this respect have proved to be just, and this investigation still remains to be completed.

To these surveys were added, in our original plan of proceeding, two comparative maps; one of the inner and one of the outer harbor; and to these has again been added, in compliance with the recommendation of our letter of August 31, 1860, a series of comparative maps, showing the changes in the inner harbor, between the years 1835 and 1847. This last series is based upon the survey of the first commissioners of the State, appointed in the year 1835, and the survey of the harbor, executed in regular course by the Coast Survey of the United States.

In the performance of the duties we have accepted under your appointment, and by the authority of the General Government, we have held two protracted meetings in Boston; the first in the month of August, when we gave a hearing to gentlemen interested in the harbor, from which we derived much valuable information, and when we supervised the prosecution of the field surveys and office work; the second in October, when we received from the hands of the Assistants of the Coast Survey their various maps, reports (written and verbal), notes, diagrams, &c., which formed the principal materials of the Report we have now the honor to submit to you.

In the course of our study of the changes of the inner harbor, we found it indispensable to repeat the survey of this region upon a scale similar to that on which the survey of the commissioners of 1835 was executed, and accordingly on the second of November we addressed you a letter upon this subject.

We acknowledge, with pleasure, the liberality with which you have responded to our requisitions, and are happy to have it in our power to say that this survey has gone on without interruption from the moment it received your approval.

In consequence of this new expansion of our original scheme of operations, combined with the necessity, not unforeseen, of extending the physical survey through at least one more season, this will not be our final report.

We shall at present refrain from making any specific recommendations, with a view either to arrest, or to counteract the existing evils in the inner harbor; either to prevent further injury, or to repair the losses already sustained. It would be inexpedient to enter upon this branch of our researches until we have before us the latest and most authentic information; that is, until the survey of the inner harbor, now in progress, is finished, and the comparative maps, of which it is to furnish the basis, are drawn.

This, our second report, will consist of two distinct divisions. The first will contain the most important particulars concerning the inner harbor, *hitherto* made known to us; omitting, as we have already said, general conclusions, and specific recommendations. The second division will contain a minute statement of the results of the surveys of the lower harbor; and this enumeration will lead us to urge upon you the absolute necessity for taking immediate steps for the efficient protection of the little yet remaining of those external shores and islands, to the defensive situation of which the outer harbor and its anchorages owe their existence.

FIRST DIVISION.

The sources of our latest information concerning the inner harbor, are the comparative maps, based upon the commissioner's survey of 1835, and the Coast Survey of 1847, drawn by Mr. A. Boschke, and the hydrographic survey of Lieut. Com'g. John Wilkinson, U. S. N., Assistant Coast Survey, together with the profiles based upon it.

The former of these comprises a series of four maps, of which

No. 1 is a reduction of the commissioners' survey of 1835, in the usual form; that is, giving the depths of water referred to a standard plane of reference, instead of the depression of the bottom of the harbor, below the coping of the dry dock, as in the original.

No. 2 is a corresponding reduction of the Survey of 1857;

No. 3 presents the Maps Nos. 1 and 2, laid down upon each other in such a manner as to show the changes;

No. 4 is so figured and shaded as to present to the eye the places and amounts of encroachment by deposits, and of improvement by deepening, where the latter has occurred.

We must repeat that the limits of the Survey of 1835 have not allowed us to make an entire comparative map of the inner harbor; nearly one half of the natural tidal reservoirs is omitted. This must be borne in mind.

Within the limits of comparison, the area occupied by solid filling, by walls, and by bridges during the twelve years constituting the interval between the surveys, amounts to about one hundred and seventy-five acres; the constructions in South Bay, south of South Boston Bridge, not included.

We are not in possession of any map showing the shore of South Bay in the year 1835, so minutely as to furnish data for a precise estimate. We can only, therefore, say of this reservoir, in general, that some ninety acres of marsh land have been dug down to low-water mark; and that this gain is counterbalanced by the filling up of the South Bay lands, or Boston flats, as they have been termed, to the extent of about eighty-five acres. This estimate is only a rough approximation; the other upper reservoirs—Charles River above the Milldam, Mystic River above Malden Bridge, and Chelsea Creek—have not suffered such material encroachments. The whole reduction may be taken at one hundred and eighty acres, including in this area a large, but undetermined extent of structures on piles, which, while they admit the passage of the tide-water, obstruct its free flow, and lead in many places to the accumulation of deposits.

In the survey we are about to undertake, particular attention will be paid to defining the line of demarcation of the solid filling and the open work; without a correct determination of this last factor, the capacity of the harbor cannot be known, and plans of improvement or preservation can only be stated in the most general terms.

Hitherto, we have spoken of the superficial measure of change. The cubic measure, during the period and within the limits of comparison, considerably exceeds a million cubic yards of filling up; the consequence of the encroachments which have taken place during the last twelve years in the channels and reservoirs of the inner harbor.

We fear that the inroads upon the water area, since the year 1847, may prove even more serious than during the same space of time previous to that date.

We should not be satisfied, however, without entering into a more minute exposition, which cannot fail to prove interesting and instructive.

We shall separate the whole area into parts; commencing with—

CHARLES RIVER.

a — From Milldam to Cambridge Bridge.

This is an extensive tidal reservoir, into which the river proper discharges itself. The channel running through depends upon the river, and is, therefore, small in the upper part of the reservoir, but deepens towards Cambridge Bridge, as the back waters of the basin begin to be felt. The gradual filling up of this basin, by natural processes alone, must be expected; so also we may look for changes in the position of its channel, owing to the soft character of the bottom, and its easy transposition. The action of the water on this basin at the end of the period of comparison, springing from natural and artificial causes, may be approximately represented in figures by saying that 433 thousand cubic yards of mud were removed, and 487 thousand cubic yards deposited. By the removal of 433 thousand cubic yards, it is not intended to imply that the area has been correspondingly deepened, but that old channels have been filled up, and new ones formed; that depths have been diminished in one place, and increased in another—minor changes, continually in progress in bottoms of soft material, subject to the action of water, moving with different velocities, and under varying circumstances. There remains a surplus of deposit, of 54 thousand cubic yards, which has taken place principally in a short channel, shown in Map No. 1, on the Boston shore, near Cambridge Bridge.

Having decided to reserve all general views for another occasion, we abstain, not without effort, from enlarging upon the importance of maintaining this reservoir.

b—From Cambridge Bridge to Craigie or Canal Bridge.

This portion has suffered very much. On this small area, there has been a surplus of deposit of more than 848 thousand cubic yards, which has destroyed a handsome channel existing in 1835, and shown in Map No. 1. We have here a striking example of the rapidity with which a harbor can be filled up, by diverting the current from its natural course, and by obstructing the flow of the tide.

Previous to the extension of the wharves at the north end of the city, the current swept the southern shore of the basin, and passed undisturbed through this section. This appears on Map No. 1. But since that event, and in connection with it, have occurred the filling up of lands in Charlestown, and on the Boston shore, at and near Canal Bridge, and also the construction of bridges across the river. The result has been to turn away the current, and to destroy its beneficial effect on the East Cambridge shore.

There is no want of character in the flow of the tide in the place where this enormous deposit has been made; but it is disturbed and irregular, marked with the inequalities arising from diversities of channel.

If an increase of velocity gives an increase of sediment, a diminution of velocity will allow a portion of that sediment to subside. It is a mistake to suppose, because the water is moving, that it will not make any deposit; or, in other words, that its transporting power is sufficient to carry the whole burden acquired at a different velocity. In the example before us the water experiences a change of velocity at the Lowell and Canal bridges, owing to changes in the course of the current, and in the area of the transverse sections; and on the ebb-tide a further modification arises from the confluence of these waters with those of Prison Point Bay. Here again we shall refrain from entering upon questions of preservation or improvement.

c — From Canal Bridge to Charles River Bridge.

In this important section of the Harbor, we find the surplus deposit no less than 547 thousand cubic yards. In an old channel, that existed in 1835 and is seen on Map No. 1, a deposit of 597 thousand cubic yards was made before the construction of the Railroad Bridge. Since then, 132 thousand cubic yards have been deposited on the Charlestown side between the bridges, making a total deposit of 729 thousand cubic yards.

The action of the current in its averted course has cut a new channel in the centre of the river, and removed thence about 182 thousand cubic yards; leaving as a surplus deposit, the above amount of 547 thousand cubic yards.

An inspection of Map No. 4 will acquaint you with the places where these changes have occurred. Here again we wait for the information to be derived from the survey in progress, before making any recommendations.

CONFLUENCE OF CHARLES AND MYSTIC RIVERS.

d — From Charles River Bridge to Chelsea Bridge, and Long Wharf.

The main features of this division have been preserved; an increase of depth has been effected in a north and south direction by the removal of a large surplus of 675 thousand cubic yards. At the mouth of the Mystic we find the channel improved by the removal of 449 thousand cubic yards, which includes a bar, seen in Map No. 1, as well as a general deepening of the channel. At the confluence of the waters of the Mystic with those of Chelsea Creek, on the ebb-tide, we find a deposit across the channel of 171 thousand cubic yards, which rests principally upon the edge of the flats at the mouth of the creek.

The outer limits of structures on the northwest corner of East Boston ought to correspond in their forms to the natural curves of the shores. Sharp angles, and re-entering curves have been, and always will be, injurious. Since the construction of wharves at that point, a deposit has taken place of 78 thousand cubic yards, which might have been avoided by a strict adherence to the simple and well-known principles of construction that apply in such cases.

We have cited these principles at length in other Reports, and may repeat them hereafter. In the mean time we shall observe to those who build under such circumstances, and neglect to conform to these principles, that they injure themselves as much as the channel; that, by neglecting to construct a water-front of a proper form, they are obliged to do that work with a dredge which nature would willingly do for them.

THE NARROWS.

e—There is a space between East Boston and Boston, the northern limit of which is a line from Constitution to Aspinwall wharves; and the southern limit, a line from Long to Cunard wharves, included in the preceding division, which we may distinguish as the *Narrows*. In general, the channel has diminished in depth. There has been a removal of about 140 thousand cubic yards on the East Boston shore, which was a natural consequence of forcing the current on that side by extending out the north end of Boston. This removal, however, is not to be regarded as an absolute improvement; for we find diffused over the remainder of this space, a deposit amounting to 287 thousand cubic yards, by which its whole capacity has been in fact diminished by the amount of 147 thousand cubic yards of surplus deposit. A considerable portion of this has lodged on the Boston shore, below the above mentioned point of extension.

SOUTH BOSTON FLATS, AND MAIN SHIP CHANNEL.

If we continue our investigations still further down the harbor, with the assistance of the comparative map of Lieut. Wilkinson, we shall find that there was deposited up to 1847, one hundred and thirty-six thousand cubic yards, within the six feet curve; and that since then, the northwestern extremity of the flats has advanced so far to the northward, as to alter very much the sailing marks for passing from Fort Point to the main ship channels. Bringing down our comparison to the present year, we find that great masses of material have been moved, the additional deposit amounting to about 1⅛ millions of cubic yards; but the removal amounts to nearly 2½ millions of cubic yards; this removal has benefited the shore of East Boston, diminished in size and depth the spit projecting from Bird Island shoal, and deepened and widened the channel about the upper middle buoy. The same action of the current that produced this last effect, has deepened the flats, also, in this vicinity; this, however, is not to be looked upon as an improvement, because the removal is not from the edge of the flats, but from the surface; and the material is deposited at a point not far below. On the other hand, with the exception of the sweep at the upper middle buoy, above mentioned, the edge of the flats has advanced upon the channel.

In general, the deposits lie principally upon the southern shore of Governor's Island, exceeding, in this place, 435 thousand cubic yards; and in the channels, where they rise to more than 466 thousand cubic yards;

leaving for the flats a deposit, by the most recent calculation, of 225,350 cubic yards.

FORT POINT CHANNEL.

The obstruction of this channel by bridges has made itself severely felt. Owing to the channel being confined through a portion of its extent to narrower limits, by the improvements of the Boston Wharf Company, the water at the heads of the wharves appears to have been maintained, or deepened.

But in this small area there has been a deposit of 82 thousand cubic yards, a part of which has taken the form of a bulkhead across the channel. Every change, by the addition of structures restraining the flow of the tide, will affect this narrow bed quickly and sensibly. It is maintained, such as it is, only by the means of the reservoir of South Bay.

Before entering into the foregoing particulars we expressed the opinion that they would prove instructive and interesting. They certainly ought to do so. They make it quite manifest that the rapid growth of the City has not been accomplished without some injury to Boston harbor; at least, without some changes which demand the most careful inquiry into their nature and progress.

The first step in this inquiry, and the one which, with your encouragement, we have already undertaken, is a resurvey of the inner harbor, on a scale minute enough, and in a manner thorough enough, to enable us to form a second series of comparative maps covering the same ground as those accompanying this Report. From these we expect to learn whether the changes we have exposed are progressive, and if so, at what rate; whether they have been effects immediately produced by artificial alterations in the beds of the channels, not liable to further modification after being once produced, or whether they are temporary in their form, and are phases of a condition liable to continual revolution.

The interval of time between the two series of comparative maps is about the same. It is not in our power to say how far these intervals accord with each other in the consumption of water space, or in the construction of bridges, &c. The latest correct definition of the shore lines of Boston harbor is that of the Coast Survey of 1847, to certain parts of which, subsequent additions were made by Henry L. Whiting, Esq., an assistant in the Coast Survey, by request of the State Commissioners of 1854–5.

It has now become requisite that these shore lines should be re-examined. If we are to look to the changes in the shore line, and to other similar improvements, for the origin of the changes in the bottom, it is desirable to know the connection of the one with the other; without which knowledge we can hardly hope to arrive at any just conclusions.

We might vary our mode of conveying an idea of the loss of water space between 1835 and 1847, as shown by the maps, by stating the depths of deposit in various places.

While conferring with you personally, having the maps before us, we did call your attention to the figures on Map No. 4, of the comparative series, by which these depths are expressed; but the figures themselves, without the maps, will have but little signification. It would hardly be possible to give them alone, without running the risk of producing an exaggerated effect.

We are desirous, on the one hand, to make the loss sustained by the harbor so apparent, that it will command attention; we are equally desirous, on the other hand, to avoid any over-statement, or to give occasion for any unnecessary alarm.

We shall not attempt to treat the subject in a general way, until all our means of information are exhausted.

In the mean time we will pass to the second division of our Report.

SECOND DIVISION.

Thus far we have confined ourselves to an almost bare recital of facts and circumstances, of which we have given the sources. Of the value of these sources you are able to form an independent opinion.

We shall pursue the same course in the present division of our Report. But here we shall go a step further, and urge upon you the duty of adopting those measures of protection, the necessity for which will be obvious.

The materials of the second division of our subject are taken from the reports, topographical maps, and hydrographical sheets, of Mr. Wm. L. Whiting, and Lieut. John Wilkinson, U. S. N., Assistants Coast Survey, and from the various comparative maps and tracings based upon the surveys of this year and those of 1847.

We shall make use of these materials somewhat indiscriminately, referring to one or another, as the occasion serves; but we will commence with the topographical work.

This has been executed under greater constraint than was anticipated. Owing to the loss of many former trigonometrical points, it was found necessary to repeat the triangulation, and determine new points; and as this labor had not entered into the estimates, it was necessary to observe the closest economy. We must do Mr. Whiting the credit to say that he has encountered the difficulties arising from insufficient means, and an unexpected extension of his field of operations, with remarkable, or rather with his usual energy and success. As a matter of justice it must be remarked that the work here undertaken by the Coast Survey, at the request of the Commission, cannot be estimated by the common standards of areas, contours, shore-lines, &c. Not only is the scale unusually large for so comprehensive a work; but there are other characteristic differences, such as the interpolation of new curves, a distinct determination of the low-water line, the careful mapping of every conspicuous rock and stone, and the consequent necessity of going over the same ground repeatedly.

The Topographical Survey comprises within its limits the islands, points, shoals, and ledges, within the harbor, which, taken in connection with the survey of Governor's and Castle Islands, made by Mr. Whiting for the Coast Survey, in 1846, furnishes a complete series of maps, on the scale of $\frac{1}{5000}$, of the main body of the harbor, from the city wharves to Point Allerton and the Graves, east and west; and from Point Shirley, on the north, to Squantum and the extreme end of Pettick's Island, on the south. The Points and Islands thus included are as follows: —

Point Shirley, including Bluff Head.
Squantum Point, with good marginal interior.
Thompson's Island, complete.
Moon Head, with small islands adjoining.
Long Island, with interior details and contour.
Deer Island, " " " "
Lovell's Island, " " " "
Gallop's Island, " " " "
Rainsford Island, " " " "
George's Island, " " " "
Pettick's Island, " " " "
Lighthouse Island, " " " "
Shag Rocks, " " " "
Great Brewster, " " " "
Middle Brewster, " " " "
Outer Brewster, " " " "
Calf Island, with interior and contour complete.
Little Calf Island, " " " "
Green Island " " " "
The Graves, " " " "
Nantasket, from Windmill Point to Point Allerton, and from Point Allerton to Strawberry Hill, on Nantasket Beach.
Little Hog Island.

To the preceding are to be added the following detached ledges and shoals: —

Great Brewster Spit.
Nix's Mate.
Quarantine Rocks.
Sunken Ledge.
Fawn Bar.
Ram Head Bar.
Devil's Back.
Half-tide Rocks.

This whole survey will be of consummate value hereafter. In details, it is full and minute, and in general scope, it is designed, by the careful introduction of every object and feature of practical importance, to furnish hereafter a reliable standard of comparison. We desire to give it the stamp of our highest approval.

The primary object of this work was, as we informed you when we asked for the means of its execution, to ascertain the present condition of the harbor, so far as that condition is characterized by merely topographical forms; and to inquire into the progress and processes of waste and accumulation, in headlands and shorelines, in points and spits, such as we know are constantly going on.

Mr. Whiting observes in his report that there seems to have been some law of drift and deposit acting upon this region of the coast, and producing the graceful uniformity observed in the undulating hills; perfect examples of which are still visible in *Powder-horn Hill*, and *Breed's Hill*, which seem to have lost none of their original symmetry. "Some persons have an impression," says Professor Hitchcock, in his *Scientific Geology of Massachusetts*, "that what is usually called diluvium, viz. gravel and boulders, was thrown together in confusion;" and he further remarks that "the usual aspect of diluvial hills, seeming to be a mere promiscuous mass of gravel and sand, is apt to confirm this idea." But the truth is, we take it that the materials of these hills were deposited under circumstances very similar to those which now govern the formation of the banks and shoals of quartzose sand on the present coast of Massachusetts. These circumstances embrace a law of deposit which we have had frequent occasion to observe. In the bottoms of our bays and sounds we shall find the same varieties of formation and condition; and we may identify the hills in Boston Bay as cases of deposit, not unlike the subaqueous deposits, but belonging to an earlier and less quiet and regular period.

In a critical examination of the Maps accompanying this Report, you frequently observe, on the bluffs and headlands, the same forms partially developed, but terminated abruptly at the precipitous cliff, worn away by the weather and the currents of the sea. In all cases, almost without exception, if the horizontal curves be continued beyond the verge of the steep bank, and joined together, the same form is renewed.

And there is little doubt that this is the original form, for the base and general outline are marked by ledges, or shoals of boulders and smaller stones,—a part of the material of the original drift, of which the lighter portion has been carried off and deposited elsewhere.

Bluff Head, Long Island Head, Moon Head, Great Brewster, Point Allerton, are apt illustrations. And it is not going too far to assume that, wherever the same kind of shoals are found, similar elevations have once stood. Tradition, and the testimony of living witnesses confirm this view with respect to Nix's Mate and Fawn Head Bar.

Where the upland has disappeared, large masses of the lighter material are found in the neighborhood. Such are the shoals at the East and West end of Deer Island, the neck joining Long Island to Long Island Head, the shallow belts of Gallop's and Lovell's Islands, the isthmus of Pettick's Island, the stony beach between Point Allerton and Nantasket, Windmill Point, Great Brewster Spit, and all similar recent formations.

You will find it interesting to continue on some of the accompanying tracings, the imaginary curves in the manner above described.

The alluvial formation of the harbor is apparently pierced by a line of rocky formation, showing itself above water in the Graves, the outer Brewster, Lighthouse Island, Black Rock, Quarantine Rocks, &c. Mr. Agassiz suggested, several years ago, that this line of direction may be taken as a guide, in searching for submerged rocks and ledges. It may be supposed that the long spit making out West from the Great Brewster, and lying under the protection of the outer Brewster and Lighthouse Island, owes its place and support to other similar ridges on this line. If so, these rocky islands, ledges, and submerged rocks, are to be regarded as permanent natural breakwaters, which will defend, to some extent, the channels and anchorages of the outer harbor, even after the higher and better defences have been lost through negligence.

It is not, however, until the physical survey of the outer harbor is completed, that we can hope to trace the *connection* between this and other spits and shoals; and the causes that have produced and are continually enlarging them.

Leaving aside these and all other general views and questions, we shall proceed to give you an account, in detail, of the degradation of some of the principal headlands and bluffs; and we shall select such cases as rest upon the best proof and measurements. It must be understood, however, that former surveys have never been made with special reference to this question.

The survey of 1847 was on the usual scale of the field work of the Coast Survey, fully answering in minuteness and accuracy to the wants of the time; to compare it with the survey of the present year, it had to be enlarged. The comparisons are highly satisfactory. But, we shall guard ourselves from exaggeration in the following statements by selecting our instances with care, and by giving results within the limits of probable error.

We will begin with Point Allerton, a conspicuous headland which forms the southern boundary to the entrance to Boston harbor. The remnants of two hills are visible, called Point Allerton Great and Little hills; the first of these is one hundred and thirteen feet high, and is still sufficiently preserved to show its original form.

The eastern portion has long since been washed away, and now presents a naked bluff to the ocean. At the present time, the whole body of Nantasket beach, to the end of Point Allerton, is extending seaward, and the upper débris has taken a slope that checks further waste. Grass has taken root naturally, on the face of the bluff, and helps still further to preserve it. Very high tides, however, rise to the base of the hill, and threaten to renew the encroachments. The portion already gone once reached a height of ninety-five feet, and amounted, probably, to fifteen acres of superficial extent; this loss occurred at the top, more than at the base.

Little Hill is a small remnant of what was once a much larger elevation; it stands at the extremity of the point. It is a fact, proved by general observation, that the high hills have a steeper slope than the low ones; and, as this little remnant of a hill rises quite abruptly from its base, to a height of about sixty feet, ending in the bluff, without any remains of the usual rounded summit, it is probable that the Great and Little hills were once nearly of the same size, forming a pair, like those of Nantasket. It would seem that the summit was somewhere between the bluff and the beacon, and the outer curve of the base beyond the latter. According to this estimate, then, the original height must have been one hundred feet, and its area forty-five acres,— larger than Boston Common; now there remains only one and a half or two acres of its southern slope, to prove its former existence.

This small residue is rapidly disappearing, and very soon the maps alone will record its former place. The northeast face of the bluff is one hundred and fifty yards in lateral extent, and sixty feet high at its highest point.

Sixty-five feet of the beach, at the point of greatest loss, have wasted away since the year 1847; the total waste of the head, since that date, is about twenty-two thousand square feet. Strong tidal currents, and heavy seas in storms, to which it is fully exposed, keep the face of the bluff almost perpendicular, and very liable to degradation by changes of weather, as well as by the action of the sea.

We have estimated the total loss at the upper surface of both bluffs, at about seventy thousand square feet.

The next example we will take up, is that of the Great and Little Brewster or Lighthouse Island. These islands form the northern boundary of the entrance to Boston harbor; the main ship channel lying between them and Point Allerton.

Lighthouse Island is a rocky ledge, of a somewhat loose and broken character, the summit and the interstices being filled with soil. It is small, exposed, and partially invaded by the sea in heavy storms, when the earth and loose rocks are easily displaced. Commander Melancton Smith, U. S. N., Lighthouse Inspector of this District, has observed that a large fragment of rock disappeared during the last season, and thinks that the encroachment towards the foundation of the Lighthouse is entitled to attention.

During the last thirteen years, the south and southeast faces of the island have been diminished to an extent which we are unable to state with precision.

The GREAT BREWSTER is always referred to as one of the most important as well as striking instances, of the wearing away of the headlands of the harbor. Here, as at Point Allerton, the general extent of the original hill can be traced, by recognizing the same principle of conformation. It was, without doubt, a long oval hill, having its axis parallel to the general flow of the water. The fragment still remaining presents on its perpendicular side a section of the original hill transverse to its main axis. The height was never much greater, probably, than that of the present summit of the east bluff one hundred and four feet. Both the east and west sides of the hill are washed away at the same time, one by the waters of the Bay, the other, by those of Broad Sound. The Outer and Middle Brewsters, and Great Calf Island have protected the centre of Great Brewster, and it is chiefly owing to these barriers that the little still remaining has been preserved.

The sea-wall at the base of the east bluff, has arrested the undermining process, but the top of the bluff and the northeast and south ends of the island are unprotected and are wearing rapidly away. The surface of the hill above the height of sixty feet, which has been lost since 1847, measures about one hundred and twenty-five thousand square feet, and the whole lost surface, including the south slope down to its base, about one hundred and fifty thousand square feet. It appears from the results of the two surveys, that the upper surface of the northeast bluff has diminished in breadth at the point of greatest loss near the summit, about one hundred and fifty feet, and the east bluff at a corresponding point about one hundred feet. These last figures are curiously confirmed by Mr. Weeks, who has lived thirteen years on Calf Island, and who reports that at the beginning of his residence there, it was necessary to walk to the corner of a stone wall, a measured distance of twelve rods from his house, to open Boston Light beyond the northeast bluff of the Great Brewster; now he sees it from the windows of his house. The bluff being about half way between his house and the Light, the loss by this calculation is one hundred feet.

The south shore of this Island has washed away for an average distance of sixty-five or seventy feet, since 1847. The greatest loss has taken place at the southeast and southwest. At the former, it amounts to one hundred and fifty feet; and at the latter, to two hundred and thirty feet of breadth. The total amount of waste, in square measure, is about seventy-five thousand feet. We are speaking now of the low shore and beach, but the encroachment has advanced to the base of the small hill or bluff on the south side, which it is now rapidly undermining. A pilot living on the island, and therefore an habitual observer, thinks that at the present rate, the degradation would in two years reach the Pilot's Flag-pole now standing thirty feet within the line of the bluff. Amid all these changes, the northwest beach on the south part of the island remains nearly as it was at the beginning of the period under consideration.

The bed of boulders and stones, lying between the Middle and Great Brewsters, furnishes a proof (the value of which we have before remarked upon) that the Great Brewster was once united with the Middle Brewster on the north, and with Lighthouse Island on the south. But without discussing this question, it is evident, from what remains of the former, that the single hills on the north must have comprised not less than thirty-six or thirty-seven acres of ground; a narrow transverse section, passing near the centre of the original hill, three and a half or four acres only in extent, still stands, and claims preservation.

A recapitulation may be useful: thirty-two acres of a hill, one hundred and four feet in height, and thirty-seven acres in extent, are entirely gone. During the last thirteen years, one hundred and fifty thousand square feet of its surface has disappeared; to this is to be added the loss of seventy thousand square feet of the south shore of the island. Lastly, there is one fact to which we wish to call your particular attention, and which, therefore, we shall place in italics:—*very soon, there will be too little of the hill left for grading upon an inclination suited to preserve its present height.*

Connected with this wearing away of the Great

Brewster is another most important and interesting feature, — the long bar or spit making out from the southwest point of the island, and extending towards George's and Lovell's islands. It is composed of coarse sand, gravel, broken slate, and stones, and is of a loose and shifting character.

We shall not undertake to trace these materials to the various sources of supply, until we enter upon the final treatment of the changes in Boston Harbor, viewed in their geological and physical aspect.

This spit is covered at high water; but at low water it shows as a narrow, winding bar, separating the main ship channel from Black Rock channel; in length nineteen hundred and thirty metres, or one mile three hundred and sixty one yards, and in average width four hundred feet. Since the survey of 1847, the ridge has risen and become more narrow; the crest is now nearly dry at high water of low neap tides. Its general position has shifted, apparently, to the northward; and this is particularly true of the west part, which has sensibly advanced to the northward and eastward into Black Rock channel; so much so that the extreme west and highest point has made out in a northwest direction as far as two hundred and fifty feet, since 1847. At that date the old barrel beacon stood on the outer point of the spit; when the iron lighthouse was afterwards built, that, also, was placed on the exterior crest of the spit, the centre of the light being about one hundred and fifty feet from the centre of the beacon.

To-day, the extreme west point is one hundred and seventy feet west of the centre of the light; and the latter now stands with about one half of its diameter beyond the southern border of the spit at low water.

We shall next take up LOVELL'S, GALLOP'S, and GEORGE'S ISLANDS, which are to be treated together, on account of their juxtaposition, and on account of their relation to that part of the main ship channel called the Narrows, the principal seat of the late hydrographic survey in the lower harbor. All three of these islands have undergone changes since 1847, the nature of which is best explained by the topographical survey, while it is, at the same time, confirmed by the hydrographic work. The north shore of Lovell's Island, from the sea-wall west has suffered considerable abrasion; the breadth at this point of greatest waste being about one hundred feet. The shore, south and east from the jetty at the south end of the sea-wall, has suffered the still greater loss of from one hundred and fifteen to one hundred and twenty feet. The sea-wall itself has protected the side and end of the island, against which it stands, and has arrested large masses of sand and stones, that entirely cover it in some places. The projecting swell of the island opposite the east end of Gallop's Island, and bounding the Narrows, does not seem to have been subjected to much alteration, except in the form of the outline of the shore; the outer curve, for example, is now one hundred and sixty feet east of its former position, and has become more blunt. Still further east, the shore line has receded about fifty feet, while the farthest point of the island, opposite the light on the spit, has gained towards the Narrows, the line of low water being further south. The soundings of the hydrographic survey exhibit a prolongation of the same changes under water, particularly in what may be called the bight of the island, where the average of the figures expressing the increase of deposit in feet is five. These figures, though not approaching to uniformity in depth, show, nevertheless, by their groupings, an entire uniformity in the places of deposit.

The east point of Gallop's Island, as defined by the high-water line, appears to be cut away, and to be much shorter than in 1847. The low-water line has encroached upon the Narrows some fifty feet; and here again the hydrographic survey shows that this same encroachment has been going on under water, the change being marked on the hydrographic sheets, by a general reduction of soundings on the north side of the island to an average amount of three feet.

The west point of George's Island has increased a little; the bight between the extreme point and the sea-wall on the north side having filled up. The southeast end of the island, between the end of the sea-wall and the stone wharf, has been considerably worn away.

Passing from these islands to the shores of NANTASKET, we find that the bluffs north of the telegraph are sharing the common fate of these exposed headlands. It is said that a few years ago, only, there was room for a cart to pass between the edge of the precipice and a small breastwork that now overhangs the cliff and is already half gone. We have introduced this and similar facts, derived from residents, and possessing, therefore, some local value, not because we think that they are to be relied upon by themselves, but because they agree with the measurement of our surveyors.

At Windmill Point, the maximum loss on the north shore has been about eighty feet; the extreme west point, opposite the nearest point of Pettick's Island, has undergone no material change. This agrees with local report. Since the survey of 1847, a steamboat wharf has been built, together with a road and bridge from Hull over to Windmill Point; these additions, co-operating with the natural law of deposit, have increased the size of the south beach, and very sensibly filled up the tidal pond inside.

Skipping over PETTICK'S ISLAND, which is of less value because it lies mostly within the outer points of the harbor, though its changes are by no means without interest, we will next take up LONG ISLAND HEAD.

This hill presents on the northeast, a steep, unprotected bluff, about six hundred and fifty yards wide, and seventy feet high.

About fifty feet of the surface have disappeared, and the wearing away still continues. On the east shore of the neck connecting the headland with the main island, there was, thirteen years ago, quite a point of high beach, projecting in a southeast direction, and affording shelter for small boats; about one hundred and sixty feet of this point have disappeared. So, also, the low point on the east side of the island, opposite Rainsford Island, has lost one hundred and fifty feet. The south shore of the island, fronting Quincy Bay, has decreased; the bluff at the extreme southwest point has also undergone some abrasion, and is still wasting away; the west shore of the neck has also diminished, making the extreme loss on both shores about one hundred and thirty feet. The total loss of this part of the island, in square measure, is about one hundred and fifty thousand feet,—a loss of some importance, when it is considered that the material removed from the upland here is probably deposited elsewhere, to the injury of the channels.

MOON HEAD, SPECTACLE ISLAND, and THOMPSON'S ISLAND, must not be allowed to occupy any room in this Report, which has already reached a reasonable limit; though we have not failed to institute as careful comparisons there as elsewhere. The superior importance of Winthrop Head and Deer Island will oblige us to give a portion of the remaining space to them.

WINTHROP HEAD furnishes one of the most striking examples in this vicinity, of a high cliff composed of coarse drift, washed and undermined by the sea. During violent storms, to the full force of which this point is exposed, the coarse materials, which are thus placed at the disposal of the currents and waves of the sea, are projected upon the shore, beyond the reach of common tides, and form either beaches or natural sea-walls (*levée de galets*), according to the distance of the place from the seat of supply.

The *beaches* are liable to great changes, both of loss and accumulation; and the stones and boulders, of which the *sea-wall* is made, are also subject to great changes of place, through the transporting power of the waves in storms. The nature and extent of these changes can only be ascertained by correct surveys, from time to time, such as form the occasion for our present investigation.

A simple inspection of the horizontal curves upon the accompanying tracing will point out, as in the case of the Great Brewster and other hills, the extent to which the destructive agencies have acted upon this conspicuous headland. It will be perceived that it is reduced to nearly, if not quite, one half of its original size, or in other words, that it has lost fifteen acres. The upper edge of the perpendicular bluff, now one hundred and five feet in height, has reached the summit of the hill. Since the survey of 1847, some sixty-five feet have been worn away from the face of the bluff; the total waste at the top is about thirty thousand square feet. The encroachment at the base of the bluff has more than kept pace with the abrasion at the summit. Our examination of the beach between Winthrop Head and Point Shirley seems to prove that some accumulation has taken place. Point Shirley itself, however, at its northern limit, has suffered a loss of forty-five or fifty feet; the total amount of loss at this point, on both sides, may be set down at about forty thousand square feet.

We describe these changes on Point Shirley and the adjacent beach, with some hesitation. There are local peculiarities of the tide, which render it difficult to make the usual allowances for surveys executed at different periods of the semi-lunation. In general, the line of high water is regarded as the limit of the shore, or line of upland; and when, from the nature of the case, this line alters extremely at different periods of the tidal course, it is not so easy to institute exact comparisons. The present survey was made at the period of the mean interval.

DEER ISLAND has undergone some slight changes. The shore of Shirley Gut is different in shape. The small point or hook east of the wharf has increased; and the northwest point, at the narrowest part of the Gut, has been cut away some thirty or thirty-five feet.

The low-water line, however, at this point remains almost precisely the same as in 1847.

The sea-walls on the east shore of the island have exerted the same beneficial influence here, in preserving the shore from further deterioration, that they have uniformly done wherever built. The upper parts of the island have suffered some abrasion, but being less exposed than many others, the loss has not been so great. A change in the form of the shore at the south end of the island has taken place; the beach fronting the beacon has receded eighty or eighty-five feet; the total waste, from the end of the sea-wall to the extreme south west point of the island, cannot be estimated at less than sixty thousand square feet. North of this point, however, on the west shore of the island, the beach has widened about as much as it has narrowed on the south; and perhaps this action may be considered rather as a shifting of material, than as an absolute loss or gain.

The shoal, extending from the south end of the island to the beacon, has undergone modifications similar to those of the Brewster Spit; it is more narrow, and heaped up to a greater height on the ridge, than appears in the survey of 1847; this shoal is dry at low water.

We are aware that the foregoing is a very tedious enumeraton of the driest possible details; and we have taken pains to confine ourselves to those instances which are, at the same time, the most conspicuous and the most important. We have omitted a great deal; and we must refer to the finished maps, for the full and satisfactory exposition of the results of our surveys. They constitute the only authentic record of the work that has been done, and they contain all the details which the scale of the survey admits, and that is all that will be really valuable in future similar investigations. It would be an endless task to undertake to describe these details in writing,—a task not only endless, but unprofitable.

We have, therefore, as we said before, only touched upon those features and those localities that are most worthy of attention; and which cannot, we think, fail to produce in your minds a twofold conviction: first, that injurious changes are going on unceasingly; and second, that the time is approaching when those who are responsible for the preservation of Boston Harbor must make up their minds either to abandon the lower harbor to its fate, or to make immediate application of the remedy—and the only remedy—by which the progress of these injuries can be arrested. This remedy is manifestly the continuation of the old and the construction of new sea-walls; a proper grading of the hills, and the planting of a suitable grass or shrub on the unsheltered surfaces. We say *manifestly*, because where the sea-walls now stand, and where grass has taken root, even on the most exposed faces, there has been no further loss if there has not been a positive gain.

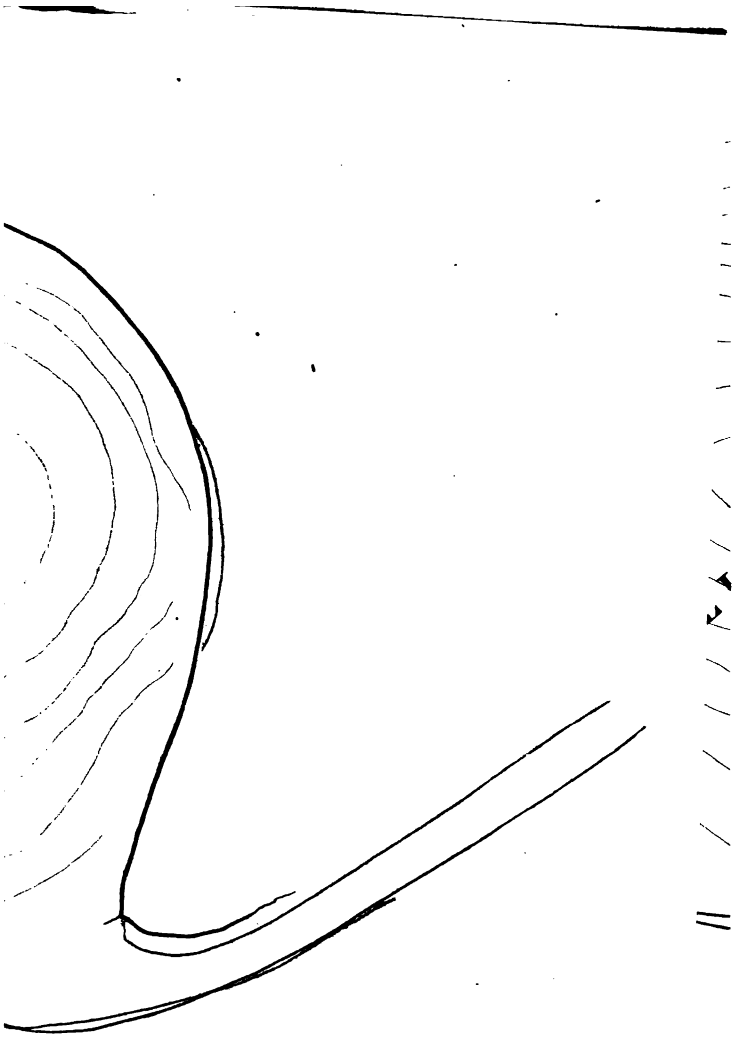
If the requisite appropriations are made for these means of protection, former plans will, no doubt, be adhered to. We shall take occasion, however, at a convenient time, to propose plans of construction in one or two special cases,—one of which, at least, is too lengthy to be entered upon at the conclusion of a report.

The necessity for immediate protection will be urged by us as opportunity may offer; and we shall advocate the adoption of the requisite measures whenever called upon to express an opinion.

Accompanying this Report is a file of tracings, designed to illustrate the text, and to be examined in connection with its perusal. Upon them the outlines of 1847 are laid down in red ink, and those of the present year, in black. They are not to be looked upon as copies of the maps. Minute and detailed copies of the latter are now in preparation, and will be transmitted to you as soon as they are finished; but a great deal of office work still remains to be done before these copies can be faithfully executed.

We have the honor to be,
Very respectfully,
Your most obed't servants,
JOS. G. TOTTEN,
Bt. Brig. Gen'l Top. Eng.
A. D. BACHE,
Supt. U. S. Coast Survey.
C. H. DAVIS,
Com. U. S. N., Supt. N. A.

To His Honor,
F. W. LINCOLN, Jr.,
Mayor of Boston.
And
JESSE HOLBROOK, Esq.,
Alderman, and Chairman of Harbor Committee, Boston.



City Document. — *No.* 12.

SPECIAL REPORT

OF THE UNITED STATES

COMMISSIONERS ON BOSTON HARBOR,

ON THE RELATION OF

MYSTIC POND AND RIVER

TO

BOSTON HARBOR.

1861.

BOSTONIA
CONDITA A.D.
1630.

BOSTON:
GEO. C. RAND & AVERY, CITY PRINTERS,
No. 8 Cornhill.
1861.

CITY OF BOSTON.

In Board of Aldermen, Feb. 4, 1861.

Laid on the table, and 1,000 copies ordered to be printed.

Attest:

S. F. McCLEARY, ***City Clerk.***

REPORT.

WASHINGTON, D. C., *Jan.* 15, 1861.

SIR: I have the honor to transmit to you the Report of the United States Harbor Commissioners, upon the subject of the proposed changes in Mystic Ponds and River (referred to in the communication of your predecessor, of January 24, 1860), which has been unavoidably delayed.

Very respectfully your obedient servant,

JOS. G. TOTTEN, Bt. Brig. Gen.,
U. S. Engineers.

His Honor J. M. WIGHTMAN,
Mayor of Boston.

WASHINGTON, D. C., *Dec.* 18, 1860.

GENTLEMEN: At the time when we had the honor to receive your communication of January 24, of this year, transmitting an order of the City Government, in which the opinion of the Commissioners upon the probable effect on the harbor, of certain proposed changes in the Mystic Pond and River was asked for, we had under review our plan of operations for the survey of Boston Harbor.

This plan embraced, among other things, a physical investigation into the motion of the waters of Boston Harbor and its tributaries.

We were about to submit to you our preliminary report, in which we had provided for a renewal, upon a more minute scale, of those tidal and current observations which had formerly been made by the Coast Survey of the United States, principally for hydrographical purposes.

Anticipating your concurrence in our proposed plan of proceeding, we thought it most judicious, and we may even say, most respectful, to defer an explicit reply to the inquiry, until our examinations were completed.

These examinations have since been made; the materials of a more minute and comprehensive report have been collected, and time has been allowed us for giving to the question more study and reflection.

The subject is one of importance, and is entitled to mature consideration on many accounts, — not the least of which is, that our opinions may exercise an influence upon the future legislation concerning Boston Harbor, a matter of general interest to the nation.

We shall arrange what we have to say in reply to your inquiry, under the following heads: —

1. The examination of the Mystic Ponds, and of the River to its mouth.
2. The results of this examination in their relation to the Estuary alone.
3. The relation of the River and the Estuary, together with their affluents, to Boston Harbor.
4. General remarks.

EXAMINATION OF THE MYSTIC PONDS, AND OF THE RIVER TO ITS MOUTH.

The examination of the Mystic Ponds and River was intended to be incidental to the more extensive physical inquiries instituted in the Harbor; and the instructions given to Assistant Mitchell, regarding this project, directed *occasional* observations by detachments of his party, and the compilation of some general notes, which should enable us to judge of the value of Mystic River in the regimen of the channels of Boston Harbor.

About the time that this work was to commence, the Mayor of the city of Charlestown, Hon. James Dana, directed C. L. Stevenson, Esq., a civil engineer of that city, to renew and extend some of the examinations undertaken a year since, regarding the propriety of using the waters of the Mystic Ponds for supplying the city. As the observations to be made by Mr. Stevenson were to be, in many respects, similar to those contemplated by Mr. Mitchell, an arrangement was entered into between these gentlemen, by which they united their parties, and thus were enabled to extend their inquiries into many valuable details, which might otherwise have been neglected for the want of time and means.

We shall now proceed to describe, briefly, the nature of the observations recorded, and the general conclusions to which they lead us.

Seven principal points were chosen, at which systematic observations of tides and currents were made in series of from twelve to twenty-four hours in duration, and many of these points were occupied simultaneously, and the observations were frequently repeated. It was not deemed necessary to continue the observations very long at any single station, since they could if desirable, be referred to the Coast Survey tidal series, at the Charlestown Dry Dock (which has been kept up for many years), and be thus reduced, in a general way, to their mean conditions.

The stations referred to are "Upper Mystic Pond," "Lower Mystic Pond," "Weir Bridge," (outlet of Lower Pond,) "Wood's Mill," "Herring Weir," "Medford Bridge," and "Ten Hills." (See Sketch marked *A*.) To these, in the discussion of the results, we have added several stations near the mouth of the river, occupied more especially for the harbor work. The approximate distances of these stations from Charlestown Dry Dock, measured along the channel, are given in Table No. 1; and in the same table, the depths and areas of sections will also be found.

Diagrams A_1 and A_2 give the observations of tides at the points we have referred to; and B_1 the currents at the same and other points. These observations are represented in curves; the figures along the top of the diagrams indicating the hours of observation; those on the side, the heights of the tide, or the velocities of the currents. The tides are plotted above a common datum line, or zero, which is 5.50 feet below the mean low water of Boston Harbor; the flood and ebb velocities of the currents are plotted above and below a zero line which marks slack water. In these Diagrams, the observations are separated according to their dates; and where several series of results are obtained at the same station, it may be seen how variable the conditions are.

Diagrams A_3 and B_2 are attempted generalizations of the phenomena, intended to present comparative views of the results at different stations, freed from anomalous changes. The numerical results, which these two diagrams illustrate, may be found with other data, in Tables Nos. 2, 3, and 4.

Tides.—When we speak of the *tides*, we mean the vertical rise and fall of the water; when of the *currents*, its horizontal motion; when of the *tidal currents*, the horizontal motion caused by the changes of level of the tides.

In reference to tidal action, the Mystic River may be divided into two parts; the one, from the harbor to some point between the Ten Hills Station and Medford Bridge, and near the latter, where the time and height of the tides are nearly the same as at the river mouth; and the other, from this point to the pond at which the duration of flood and ebb is abnormal, if considered with reference to tidal currents, and where the simple river regimen of downward currents predominates.

The curve *aa'* (see Diagram A_3) represents the tides as observed at Charlestown Dry Dock. It is normal in character, and has yet undergone but little change of form since leaving the ocean. From other observations made by the Coast Survey, it has been determined that the wave travels the entire distance from Boston Lower Light to the Charlestown Dry Dock in twelve minutes, and that all parts of the wave suffer the same delay in this journey. The changes of depth, from hour to hour, in the channels of the harbor, due to rise and fall of the tide, are not in so great ratio to the total depths of water, as materially to vary the friction, and thus to cause sensible irregularities in the rate of wave propagation.

Beyond the Dry Dock, as our point of observation advances up the Mystic River, we find the shallower channels causing greater delays in the progress of the tide wave, and so varying their sections at different stages of the tide, as to make this delay irregular, — being least at high water, and greatest at low water. The currents also vary the apparent rates of the wave motion, as we shall show.

The tide wave at Ten Hills, *bb'*, is very slightly displaced to the right, upon our diagram, — it has suffered a delay of five minutes for high water and twenty-four for low water. The form of the curve *cc'*, representing the tide at Medford Bridge, is sensibly disturbed from its position at the Navy Yard, — having suffered fourteen minutes delay in high water, and fifty-two minutes in low water. The tide wave is propagated with some regularity thus far, and for a certain distance beyond, though not so far as Herring Weir, where the curve *dd'* represents the law of rise and fall, and is sharply interrupted three hours before, and three and a half hours after, high water, suddenly changing to a nearly straight line on both flood and ebb when the level of 11.64 feet is reached. There are then sixteen inches of water in the thread of the stream, the bed of which is here about 4¼ feet above mean low water of the harbor. The curve *ee'* represents the corresponding phenomena at the dam at Wood's Mill. The form of the flood-tide curve is here but little, though somewhat affected after the rise commences; but that of the ebb is not a true tidal fall, even while the depth remains considerable. The water must rise to about 12.8 feet above our datum line before the tide commences its rise; and on the ebb, it ceases to fall about the time that this plane is again reached. High water occurs forty-two minutes later at this place than at the Dry Dock, but the level reached is about the same. The tide of Weir Bridge is shown by the curve ff'. The horizontal of 14.15 feet represents the river ebb, and the depth of water is then 3½ feet. The height reached by the tide is less than at Wood's Mill, but high water occurs at nearly the same time. The exceedingly small rise and fall in the upper and lower Mystic Ponds, is represented by the curve gg'. The tide-water is not admitted to the ponds in sufficient quantity to vary their levels greatly. The greatest rise and fall due to tides, given in Diagrams A_1 and A_2, is about $\frac{2}{10}$ feet, an inconsiderable quantity when compared with the rise following the freshet of September 13, as exhibited on Diagram A_2.

The surface of this pond, as shown on Diagram A_3 lies below high water of the Harbor; but it must be remembered that these observations were made at a dry season. We may state, generally, then, that *the tide rises to the same absolute height, at high water, in all parts of the Mystic River, from the Harbor to Wood's Mill, although the delay in reaching its greatest altitude varies (increasingly) as we ascend the river. It is only during the dry season that Mystic Pond can be in any sense classed as a tidal reservoir, and, even at this period, the presence of the tide in this basin is to be discovered only by careful observation.*

Thus far, we have spoken of the tide as a wave. It is propagated from sea at rates varying from fifty miles an hour (its velocity from the entrance of the Harbor to the Dry Dock) to about two miles an hour in the upper portion of Mystic River. So rapid is the increase of the permanent causes of delay (friction and the like) in the latter portion of this journey, that the rate of wave propagation becomes less than the possible velocity of running water; we are not to expect, therefore, that the advance of the tide wave will be uniform, if currents, even while the depth and section remain constant, traverse its path. At Wood's Mill, as we have seen, the part of the tide above a certain height maintains its wave character as its rising portion advances in a favoring, or only feebly opposing, stream; while its falling portion, struggling onward against the combined opposition of river and ebb tidal current, is retarded in such unequal ratios that the symmetry of the figure is destroyed.

From what we shall have to say hereafter of the currents, it will be understood that a very small increase of head in the Mystic Pond, without enlarging the section very considerably at Wood's Mill, may make the velocity greater than the rate of travel which we have shown for the tide; at such times there may be a gradual backing up of the stream, as by a dam, but nothing like a symmetrical tide. The Herring Weir tide shows also the peculiarities we have described as presented at Wood's Mill. *Under ordinary circumstances, Wood's Mill may be regarded as the point where the true tide wave ceases.*

Currents. — Referring to Diagram B_2 and the tables we have already mentioned, we find that at the station off the Dry Dock the maximum of flood is reached at about two to three hours after the slack water of ebb, descending more gradually to the slack water of flood, in about three or four hours, making the duration of flood about five and a half hours; the mean from the observations is 5h. 27m. The ebb exceeds in velocity and duration the flood, owing to the river influence. At Medford Bridge (curve *ii'*), the flood current rises to a maximum of 1.50 miles per hour, in two and three quarters hours from slack water, and declines in two hours to the next slack, its duration being but about 4h. 56m. The great excess of the ebb, as well as the form of the flood-current curve, shows the influence of the river waters, the depth and section. The duration of the prolonged ebb here is nearly seven and a half hours.

At Wood's Mill (curve *ll'*, the station lies below the dam), the flood is small in velocity and duration, the force of the flood tide from the harbor being exhausted in checking the river current to about 1.35 miles per hour, which runs steadily for ten and a half hours out of twelve and a quarter.

At Weir Bridge (curve *mm'*, Diagram B_2), the features are similar to those at Wood's Mill, the velocity of the flood being increased at a maximum to 1.40 miles, and its duration diminished to one and three quarters hours. The rapid increase of ebb velocity to the point where the river current alone acts, uninfluenced by the tidal current, is well marked in the curves for both Weir Bridge and Wood's Mill, by the horizontal line denoting a constant current.

Let us now trace the hourly conditions of the river during an entire tide. Diagrams C_1 and C_2, are made out from tables already spoken of, and as many stations are used as the scale of the plotting will admit. C_1 corresponds to the flood, and C_2 to the ebb. The relative levels of the surface of the river are given for every hour as marked, and the direction and magnitude of the current at that time are shown by an arrow,—the direction by the head, and the velocity by the length of the shaft. Connecting the points of the arrows (by a broken line in sketch), we have the curves representing the velocities of flood and ebb. The time of slack water is shown as that in which these curves cross the axis. A section of the bottom of the river, and position of the pond, is given on the same diagram. The arrows of different stations are connected by a dotted line, to show the inclination of the water surface. From these diagrams we easily deduce the character of the river, as to tides and currents, at any time, corresponding to these observations.

When it is low water at Charlestown Dry Dock, the Mystic presents the following peculiarities: The surface is lower in the harbor than at Ten Hills Station, where it is not yet low water, and where there is little current. At Medford Bridge, the surface is 0.98 feet above the level of the water at Ten Hills, and there is a downward current of 1.68 miles per hour. At Herring Weir, the surface is 4.61 feet above the water-level at Medford Bridge, and a downward current of 1.36 miles prevails. At Wood's Mill, at this time, the surface is 1.19 feet higher than at Herring Weir, and there is a strong downward current of 1.36 miles per hour,—the Mystic Pond is pouring out its waters.

The tide rising, in about an hour the level of the water at the Ten Hills Station is below that of the harbor and of Medford Bridge. A flood current prevails off the Dry Dock of 0.3 miles; while at Medford Bridge it is still flowing downward at the rate of 1.54 miles per hour. These two currents conflict in the space between these stations, and slack water occurs near Ten Hills. It is evident that whatever is brought in by the flood from the harbor, or down by the river, must be deposited at this time along the slack-water region. This slack current travelling up the river, as the point of greatest depression, does not reach Medford Bridge until above an hour after low water at the Dry Dock. The flood current reaches its maximum of 0.4 miles per hour at Ten Hills Station about two and a half hours after low water, declining slowly to the high-water stand, about eight minutes before high water. The current at the Ten Hills Station is a normal one, following the general law of the harbor currents.

At Medford Bridge, the flood current reaches a maximum of 1.31 miles at three hours from low water.

The level of Wood's Mill Station is reached by the waters at Ten Hills Station four and a quarter hours after low water, and by the water at Medford Bridge but a quarter of an hour later. Although the river is never actually level from its mouth to Wood's Mill, yet there is an approach to this condition four and a quarter hours after low water off the Dry Dock. At this time there is a flood current of 0.30 miles off Dry Dock, and at Ten Hills; of 1.17 miles at Medford Bridge, and a downward current of 1.20 at Wood's Mill.

About one hour before slack current of flood at Ten Hills, the river has reached the level of the Mystic Pond, and after this time flows into it. About the time of slack current at Ten Hills, the flood current at Wood's Mill has a velocity of 0.44 miles. The duration of flood current at Ten Hills is nearly 5h. 50m.; at Medford Bridge, 4h. 56m.; at Wood's Mill, about 1h. 46m.; and about the same at the entrance to the pond.

The ebb current at Ten Hills increases to a maximum of 0.60 miles per hour, three and a half hours after high water, and continues at a nearly uniform velocity for two hours; after which it declines rapidly, reaching its slack after a duration of 6h. 45m. The ebb current begins at Wood's Mill about three quarters of an hour after local high water, increasing in two hours to a velocity of 1.30, and in three and a half hours to a velocity of 1.40 miles, from which it varies but little through seven and a half hours. At this point the ebb current (downward) runs ten and a half hours.

At Medford Bridge, the ebb current begins only twenty minutes after local high water. It lasts about seven and a half hours.

On Diagrams D_1 and D_2 are given comparative views of the durations of the flood currents, and the durations of slack water from station to station. In the first of the diagrams, the influence of land waters can be traced, these having a tendency to destroy the flood current, or shorten its duration. The duration of this current increases as we leave the Mystic Pond, and descend the river, reaching a maximum at Ten Hills, and diminishing but little at a station near the Boston and Maine Railroad Bridge. Below this the Malden River debouches; and at the station between Chelsea and Malden bridges, — notwithstanding the Mystic has here a great section, — the duration of flood lessens to the same value as at Medford Bridge. In the deep waters off Charlestown Navy Yard, the duration of flood again increases, but by reason of the influx of several more land streams, the flood, even here, does not regain the duration observed at Ten Hills. The capacity of the channel at Ten Hills is to that at the Navy Yard as 1 to 40 for low water, and as 1 to 10 for high water; so that the little influence which the Mystic Pond, Alewive Brook, and other feeders of the river have, as low down as Ten Hills, can scarcely affect the times of the current at Charlestown Navy Yard, especially at low water. We are safe in asserting, therefore, that *the outflow of Mystic Pond does not produce a measurable effect upon the times of the currents in Boston Harbor below Charlestown.*

The upper portion of the Mystic River is traversed by a predominating ebb stream of considerable scouring power, which no doubt wears away its gravelly bed gradually, and deposits the debris at a lower point in the river, perhaps below Ten Hills, where the feeble currents are interrupted by long periods of slack water, which offer opportunities for deposits. On Diagram D_2, the comparative durations of slack water are exhibited. The greatest duration occurs between flood and ebb, at the Boston and Maine Railroad Bridge.

If we assume that one half the difference between the maximum velocities of ebb and flood is the velocity of the outflow of land waters, (this supposition is not exact, but is not greatly in error,) this would give, for the velocity of the outflow at Ten Hills, about one tenth of a mile per hour at the season of our observations,—*a force which would be inadequate of itself to effect any scour; but, united with tidal currents, it has become an important element in the maintenance of the channel of the estuary.*

RESULTS OF THIS EXAMINATION IN THEIR RELATION TO THE ESTUARY ALONE.

De La Beche, in his memorandum on estuaries and their tides, has justly observed that the present and actual state of any estuary, or tidal river, may be considered as an *adjustment*, for the time, of the several parts or materials of which it is formed. So also the *regimen* of a river is correctly defined to be a state in which the bed of the stream is equal to the reception and discharge of all the waters (whether river or tidal) that it can be required to pass; and further, the resultant of all the conflicting forces that act upon it, by means of which regularity and uniformity of motion in the stream are preserved, and the same flow is secured under similar circumstances.

We have just seen what the adjustment and regimen of the Mystic River and Estuary are at the present time. We have seen—

1. *That it is only during the dry season that Mystic Pond can be classed as a tidal reservoir; and that even then the presence of the tide wave in the basin is scarcely appreciable.*

2. *That under ordinary circumstances Wood's Mill may be regarded as the point at which the true tide ceases.*

3. *That at Wood's Mill the ebb (downward) current runs ten and a half hours, and that at Medford Bridge, it lasts about seven and a half hours.*

4. *That the influence of land waters tends to destroy the flood current, or shorten its duration; that this duration reaches its maximum in descending the river at Ten Hills; and further, below the Railroad Bridge, where Malden River falls into the Mystic, notwithstanding the increased section of the latter, the duration of the flood is again diminished to the same period as at Medford Bridge.*

5. *That even in the deep waters off Charlestown Navy Yard, by reason of the influx of several more land streams, the flood does not regain the same period of duration that it had at Ten Hills.*

6. It will be observed, we are speaking here of the effect of the influx of the lower streams upon the duration of the tide, and not of Mystic Pond, Alewive Brook, and other upper feeders of the river.

7. In relation to the latter we have observed that *the outflow of Mystic Pond does not produce a measurable effect upon the times of the currents in Boston Harbor below Charlestown.*

8. *And finally, that the velocity of the outflow, being added to that of the tidal current, forms an important element in the maintainance of the estuary of the channel.*

This last deduction is the consummate result and consequence of all the preceding conclusions; and points out the nature of the relation existing between the estuary of the Mystic, and the tide and river waters above that estuary.

That relation may be embodied, in general terms, in the following statement: —

If the materials forming the bed of a stream are of the rolling description, as sand and gravel, land streams, having velocities less than one-half mile per hour are quite inadequate to their removal. Again, if a channel is traversed by equal and opposite tidal streams, however violent, the rolling material forming its bed is but borne to and fro without ultimate removal. But, if the channel of a river is traversed by both land streams and tidal currents, with conditions as above, a very considerable scouring power may be the result, and the material may be permanently removed. If a flood current fails to set in motion a pebble which it encounters, it is because the force is exhausted in overcoming the inertia and friction; but this force, if aided by the ebb-tidal current, may become powerful enough to roll this pebble a considerable distance; while, on the other hand, the same force, by resisting the flood-tidal current, prevents the return of the pebble; and thus it makes a daily seaward gain. The velocity of the river current is but one tenth of a mile off Ten Hills Farm, but, united with the ebb, it becomes six tenths,—a force equal to the scouring away of sand and ordinary gravel. The same land stream resisting the flood, reduces the force of the latter to four tenths, —a power incapable of overcoming the inertia of gravel, and, therefore, unable to undo the work of the ebb.

If we calculate the work executed in a given time,—a half tidal day, for instance,—by determining the resultant power, on the supposition that all the forces act simultaneously, we shall have the following as the relative results:—

Off	Charlestown,	assumed to be	1.
"	Ten Hills	becomes	1.
Under	Medford Bridge	"	11.
At	Herring Weir	"	8.
"	Wood's Mill	"	14.

The greatest scouring power is exerted at Wood's Mill, upon a bottom of gravel and small shingle. At Herring Weir, a similar bottom is found. At Medford, a gas-pipe forms a solid dam. At Ten Hills, mud is found, except in the centre of the channel, where the bottom is gravelly.

Our conclusion in the special case of the Mystic, it will be remembered, is derived from observations made at the season the least favorable to the complete display of the relation between the upper and lower Mystic, in all its value.

A considerable portion of those large masses of mud lands, which are found in all such places, are deposited on the top of the flood tide, and especially at those periods when the agitation of the water, under the influence of violent winds, disturbs the bottom and sides of the channel. The lighter material is carried upon the shoal ground to the highest level attained by the tide, where the water becomes quiet, and the currents of the ebb have but little appreciable velocity, and no determinate direction.

The current of the ebb, therefore, carries back only a part of the material. Every successive tide, for a certain time, increases in this manner (however slowly), these banks of mud that are to be seen wherever the tide flows. Now, the freshes and the tides of the syzygies, and particularly at the equinoxes, have great influence in remedying this evil; and this influence is especially beneficial when the freshes concur with the most powerful spring tides.

During the lowest stage of a river, the power of the flood may *possibly* be superior to that of the ebb increased by the fresh water, and aided by the inclination of the bed; but, on the other hand, during the freshes and high tides, the power of the flood is far inferior to that of the ebb increased by the fresh water.

The ordinary ebbs would not be able to preserve the lower channels, if they were not assisted by freshes and extraordinary tides.

And the two latter not only act with an immediately beneficial effect upon the lower channels, but they keep open the upper reservoir, and make it a more perfect receptacle for the tide water, which acts with a proportionately greater scouring power, on its return to the sea.

If the water of the rivers did not, in this manner, combine with the ebb tide, or in other words, if, for any reason whatever, the flow of the river were arrested, the channel below the obstruction would be very soon, by the action of the sea, filled up, and the river bed would become a place for cultivation.

This has been exemplified in a remarkable way, in the river Somme.

A lateral canal was constructed along this river from Abbeville to Saint Valery. This canal being sufficiently large to carry off the waters of the river, it was thought advisable to build a dyke in the neighborhood of Abbeville, and divert the waters from their natural course. The filling up of the bed of the Somme was an almost immediate consequence of these arrangements.

But let us consider the effect of the tides in a channel like that of the Mystic, independently of the waters of the river. We have already said that the ordinary flood tide leaves behind it a portion of its sedimentary matter.

But under the most unfavorable circumstances, the ebb current will carry back with it a great part of the alluvial mud. This current may not be entirely efficacious in maintaining the channel in its best state, but it is efficacious to a certain extent.

If we suppose the waters of the flood to be arrested, and become stagnant, after having attained their greatest height, the whole of the matter held in suspension would be deposited. This stagnation of the waters of the flood will be, in a measure, brought about by the construction of a dam at a point below the point of highest ascent of the tide water. The current of the flood will be stopped by this barrier, — the water will be brought to a state of repose, the state most favorable to deposit.

When retiring on the ebb, it will acquire no appreciable velocity until it has reached some distance below the dam. In this space, it will not have sufficient force to remove the mud, and a deposition will consequently take place, even during the ebb; and the filling up will be very much more rapid than if the dam did not exist.

The loss of the navigation of the channel will follow as an immediate consequence. This is exemplified again, in the filling up of the channel below the obstruction of the Little Vay, of which we shall say a word directly.

In the adoption of what is called the "lower level," in the Report of Messrs. Baldwin and Stevenson, we have to consider the effect upon both the upper and the lower part of the river, of the proposed dam.

Wherever a dam, bridge, or weir has been built across a river, it has been observed that the alluvial deposits, whether of sand or mud, brought up by the flood, accumulate very rapidly,—particularly in the neighborhood of the obstruction; and in this way, a quick and sensible diminution of water capacity takes place. The effect is sometimes counteracted in a measure, by freshes, or by the action of equinoctial spring tides.

It is, however, only for a time; navigation is soon materially injured, if not altogether destroyed. During the dry season of the year, the return on the ebb of the waters brought in by the flood — the action of the river itself at this season being small—is the principal part of the force by which the channel is kept open. If a bar opposes the progress of the flood tide, the waters, brought to a state of sluggishness, leave their burden in the channel.

We have satisfactory and conclusive evidences, on a larger scale, of the effects of these kinds of interruptions in the rivers Aure and Vire, in the department of Calvados.

The latter, leaving the interior, enters the Bay of Vays, where it winds through sand and mud for a distance of about seven and a half miles. About one third of the way down the bay, it receives the River Aure, which comes from another part of the same department. The Aure was first barred by two bridges with flood-gates, constructed in the town of Isigny, and M. Lejeune, the engineer-in-chief employed in building a quay wall, proved that the existence of these obstructions had diminished the depth of the river in front of the town, below the bridge, by about three feet. Subsequently to this, the River Vire was obstructed by a bridge with flood-gates, called the Bridge of the Little Vay, and after some years, the channel of the bay had altered to such a degree that it was found impossible to reach the port of Isigny, except in vessels of reduced tonnage.

During the spring tide of 1840, there were only five feet of water at full sea at the entrance of the port, and vessels of small draught found it impossible to enter.

For reasons not given, it was decided not to remove the obstructions built upon the Aure; but as there existed no objection to removing the bridge of Vay, for the purpose of opening the pass to the bay, and rendering the approaches to Isigny more convenient, the question was submitted to the Council of the *Ponts et Chaussèes.*

The Council adopted this course, and gave a sketch of the opinions which the consideration of the subject had called forth.

The administration of the *Ponts et Chaussées* had previously adopted this view, when in 1816 it abandoned the project of obstructing the River Scorff, above the Port of Lorient, by a bridge with flood-gates.

M. Lamblardie, the younger, showed that this work, by cutting off the receptacles above, would lead to the rapid filling up of the channel, and this, by depriving it of the flow of the waters introduced by the flood into the upper reaches. The work had been commenced, and the bridge was constructed over one half the breadth of the stream, when the rapid deposition of alluvium below brought the Council to the unanimous conclusion that it was necessary to arrest the evil.

M. Cordier relates that before the establishment of the sluice in the rear of the port of Dunkirk, the sea entered twice a day, overflowed the vast plain of Waltéringues, and twice retreated. In this manner, the port was traversed twice a day by an immense current, which opened the channel, and maintained the passes of the roadstead.

Since the construction of this sluice, the natural scour has ceased; the deposits have closed the entrance of the harbor; the beach, extending itself more and more, has become continuous, and the passes of the roadstead have contracted. The same results have taken place at Gravelines; the sea formerly ascended to Saint Omer (the resort of vessels), and covered twice a day a plain of several square leagues in extent.

The channel of Gravelines was kept in a good condition, and the creek at the foot of the sand hills at Gravelines was preserved by the natural scour; the navigation of both ports was improved.

The sluices of Gravelines have changed this state of things; the sea has been kept out, the channel has filled up with mud, and this port, formerly a very valuable one, is almost abandoned.

What we have already said goes to show, that the loss of the port of Isigny was owing to the existence of the bridge, with flood-gates, of the Little Vay; after having, however, cited valuable opinions that directly sustain our own views, we will notice others not less valuable, which might seem, at the first glance, to be opposed to us.

We allude here, particularly, to the use of dykes and jetties in improving the navigation of rivers, examples of which are frequent in Great Britain and on the Continent.

The example of the Seine is brought to our notice in connection with a discussion which took place at the time it was proposed to construct a dyke at its mouth; and in this same class of improvements enter several of the English rivers, such as the Clyde, the Tay, and the Dee.

But M. de Prony, in his memoir, has drawn the distinction between transversal obstructions, like the bridge of the Little Vay, or the proposed dam of the Mystic, which impede the natural flow of the waters of a tidal river, and those jetties, which, being designed to limit the capacity of a channel, add to the condition of being submerged, that of being so placed as to give a special direction to the downward flow.

Speaking of the jetty at the mouth of the Seine, he describes it as being in some sort a prolongation of the shore of the Continent. If, on the contrary, the jetty in question was placed two leagues above the mouth, and was similar in its character to those we have condemned, the part of the Seine comprised between the jetty and the mouth would rapidly fill up. M. de Prony, speaking of the plan of M. Sénéchal says: "M. Sénéchal places his jetty at 9,000 metres (29,528 feet) above the position adopted by M. Pattu, and it would no longer fulfil the condition we have previously mentioned of being a prolongation of the coast of Calvados," (similar in character to Mr. Walker's piers at the entrance of the River Tyne.) "If carried into execution it would leave an indent deeper and more extensive than that in front of the jetty of M. Pattu. In this case, the ascending tide would leave there its alluvial burden. M. Sénéchal was far from denying this effect himself, and, to avoid the difficulty, he furnished his jetty with flood-gates."

These opinions of M. de Prony are cited from the report on the bridge of the Vay, of the Council of the *Ponts et Chaussées*, which report concludes with the declaration that what has been said of the Seine, applies to the Vire, and to all other rivers. In consequence of this report, an order was given to the engineers of Calvados, to remove the gates of the bridge of the Vay, and to let the waters of the sea enter the valley of the Vire.

This order was executed; and the force of the current not only cleared out again the passes of the Vay, but also opened a new bed for the Vire, over ground, which, though of modern formation, had already begun to acquire some consistence. It was observed that the result of the improvements was to restore to navigation the facilities it enjoyed before the construction of the bridge of the Vay.

We might bring forward other examples of the injury done to rivers and their navigation, by means of bars placed within the reach of the tidal water; but our views are sufficiently illustrated.

Having shown what effect the damming of the Mystic will have upon the beds of the river and estuary, we shall pass to the third head of our Report, in which we are to point out the connection between the estuary and the harbor.

RELATION OF THE RIVER AND ESTUARY, TOGETHER WITH THEIR AFFLUENTS, TO BOSTON HARBOR.

We have already, under the preceding head, made some incidental remarks touching upon this topic, particularly where we spoke of the effect produced by the Mystic and a portion of its tributaries upon the times of the tidal currents off Charlestown; these remarks we need not repeat.

The whole inquiry under our present head ought to be satisfactorily answered by simply stating the relation that exists between the harbor and the Mystic; a relation at once of reciprocity and dependence; of reciprocity, arising from the mutual interchange, twice a day, of the tidal waters of the ocean, retarded or accelerated by the land waters; and of dependence on the part of the harbor, because the Mystic is one of the two inner receptacles, or reservoirs, without which the present capacity of Boston Harbor could not be maintained.

Tidal harbors, like that of Boston, owe their preservation to the basin or basins in their rear, in a degree varying with the size of the rivers, or streams, which find through them their channel to the sea.

If there is no river, as in the case of Portland, the harbor is wholly dependent upon the interior basin. But where there is a river, which is a receptacle for tidal water, and at the same time possesses an independent maintaining power, the relation of the interior basin loses some of its importance. This is the case, also, where there is a double opening to the sea.

It would be easy to draw from the Atlantic and Gulf coasts of the United States, examples of the various kinds of harbors that are peculiar to alluvial shores; of tidal harbors that, having no interior basin or reservoir, are fast hastening to decay; of such as depend upon interior basins, exclusively, for their preservation; of tidal harbors, which owe their existence and maintenance to interior reservoirs and rivers combined; and of harbors, which have no regular or influential tides, and are simply the outlets of rivers.

Boston Harbor belongs to the third of the classes above enumerated.

The reservoirs and rivers inside it and above it constitute the original sources of its existence, and the efficient means of its preservation. If they are taken away or diminished, Boston Harbor is taken away or diminished.

In the first division of our second Report on Boston Harbor, we offered you a precise and definite illustration of this view. Under the head of *The Confluence of the Charles and Mystic,* we remarked that "the main features of this division have been preserved; an increase of depth has been effected in a North and South direction, by the removal of a large surplus of 675,000 cubic yards. At the mouth of the Mystic, we find the channel improved by the removal of 449,000 cubic yards, which include a bar seen in Map No. 1, as well as a general deepening of the channel."

And under the head of *Narrows*, also, we noticed the removal of a large amount of deposit on the East Boston shore, which removal, while it was a natural consequence of the diversion of the current of that side, proves, at the same time, the power of the current. And again, under the head of *South Boston Flats, and Main Ship Channel*, we mentioned another removal of deposit, which had benefited the shore of East Boston. A simple inspection of comparative Map No. 4, will enable you to trace the influence of these combined streams in the new channel which they have scooped out for themselves, down even into the mouth of Fort Point Channel.

It might be said, and truly said, that the old channel of the inner harbor affords as satisfactory an evidence as the new one, of the mutual relation and dependence existing between itself and the estuaries above it. Undoubtedly it does afford the same proof; and this brings us back to the first observation under this head, that the whole inquiry ought to be satisfactorily answered by a simple statement of this relation and dependence. In fact, it carries us back to that fundamental principle laid down by the first Commissioners on Boston Harbor, appointed in 1835, "all engineers of eminent scientific attainments," in language that cannot be improved either in perspicuity or simplicity. But a novel force seems to be given to the illustration, a fresh elucidation of the subject seems to have taken place, when we see the waters of the Charles and Mystic compelled, by artificial means, to abandon a portion of their former bed, executing, in a comparatively short space of time, a task corresponding to that capacity and power which had been previously assigned to them.

We have endeavored to give an idea of the comparative work, or scouring power exerted at different places in the Mystic, by combining the periods and velocities of the ebb tide. If we multiply the figures expressing the results by the sectional areas at each place, we shall obtain the relative momenta. Taking the section off Charlestown to be unity, as before, we have:—

Off Charlestown - - - - -	1.
Off Ten Hills - - - - -	0.08
Under Medford Bridge - - -	0.09
At Herring Weir - - - -	0.08
At Wood's Mill - - - -	0.10

We may conclude, then, that although the action upon a given area of the channel-bed at Wood's Mill is fourteen times as great as that for the same area at the station off Charlestown, the tidal power which would be exerted in a given time, were every water particle in both cases in contact with the channel-bed, is but one tenth as great in the former as in the latter instance.

The attempt might be made, perhaps has been made, to underrate the value of the Mystic by a comparison like the above, which is eminently partial and fanciful. This view of the relations of one part of the harbor to several parts of the interior basin taken separately, presents a comparative estimate, accurate in its facts so far as they are stated, but inaccurate in its omission of other facts equally significant, and indispensable to an entire and comprehensive statement of the whole subject. We do not, however, admit that any just argument tending to depreciate the importance of the estuary and river, could be derived from this comparison, meagre and circumscribed as it is. The case involves a fundamental principle, into which the question of more or less does not enter, except through that subtilty of argumentation which aims to gain its point by means of excessive refinement, or by the assumption of an extreme quantity. But we will not give more time than is necessary to a course of reasoning that exceeds the true limits of the inquiry. The following numbers, which we introduce without further preamble, will serve to show the importance of the tide waters of the Mystic Reservoir to the inner harbor of Boston.

1. The area from Charles River Bridge to Chelsea Bridge, and to the Narrows, is - - 398 acres.
2. Of the Mystic Reservoir - - 480 "
3. Of 1, with the addition of the Narrows, 584 "

So that the surface of the tidal reservoir of the Mystic is actually greater than that of the space between Charles River Bridge, Chelsea Bridge, and the Narrows, and nearly equal to that space, with the addition of the Narrows.

4. The surface of the tidal prism between high and low water within the same limits as in 1, is 80 acres.
5. Of the tidal prism of Mystic River, 480 "
6. Of the tidal prism, as in 3, 91 "

So that the Mystic Reservoir tidal surface is more than five times the corresponding surface of the inner harbor between Charles River Bridge, Chelsea Bridge, and the

Narrows inclusive, bringing into strong relief the value of the Mystic flats and meadows overflowed at high water.

7. The cubic contents of tide water (the tidal prism within the limits specified in 1) are 5,770,000 cubic yds.

8. The cubic contents of the Mystic River tide water are - - 8,410,000 " "

9. The cubic contents of the part of the inner harbor specified in 3, including the Narrows, are - 8,710,000 " "

It certainly is not needful to subjoin to this comparative statement a recommendation that nothing be done for any purpose, or under any pretext whatever, permanently to impair the usefulness of the Mystic Reservoir; or, should this be thought expedient, we certainly may spare ourselves the trouble of elaborating an argument, or uttering by anticipation a complaint. We have endeavored to give our views in a manner at once intelligible, and free from the liability of misapprehension. If we appear, by the form in which we have presented them, to advocate their adoption, it has been the natural result of strong convictions, and not of partial motives or feelings.

GENERAL REMARKS.

The preceding part of this Report possesses the character of an essay, or series of notes with conclusions, which it has been thought advisable to arrange under separate heads, in order more fully to show the method and connection pervading them. We shall pursue a similar course in what remains to be said, though for a different reason. The topics still to be treated are somewhat desultory, though all having a direct bearing upon the main inquiry contained in your order of the 23d of January. This bearing we are careful to define, pointing out distinctly the precise place which each one of our separate discussions is designed to occupy in the general views or plan of this Report. The subdivisions under this general head are as follows: —

a — *Estuary as a Reservoir.*
b — *Reservation of the Mystic Pond Waters, and employment of Sluices, or Flood-gates.*
c — *Mr. Stevenson's View.*
d — *Mystic Lower Pond as a Reservoir.*
e — *Characteristics of the Mystic and other Ponds.*
f — *Recapitulation.*

a — *Estuary as a Reservoir.* The views concerning the reservoir given under the third head, at the end, really require no corroborative testimony or support; yet, to elucidate the subject, and to satisfy the general judgment, we will cite some instances and authorities in point, showing the disadvantages that have resulted from preventing the "tidal inflow," or the "inflowing of more than ordinary tides," into the rivers, and inner and upper reservoirs of tidal harbors, and the conclusions to which distinguished inquirers have been carried by the most systematic and thorough research.

The Commissioners on Tidal Harbors, appointed by Royal Commission, in April, 1844, say, in the prefatory remarks of their first Report: "We find that very great and increasing injury to the best interests of the country has accrued from negligence of the several authorities in permitting the improper removal of soil and beach, as well as by *embankments, weirs, and other obstructions of a similar nature, which check the free flow of the tide, impair its strength, and thus permanently diminish the general depth of the river.* And, on the other hand, that when the aid of experience and science has been called in, and a due vigilance has been exercised, a proportionate improvement has been invariably the result." And it cites the following instances as cases in point.

It is given as a reason for the tardy improvement of the River Clyde, "that weirs have been permitted across the river, nay, sanctioned by Act of Parliament (49 Geo. III, cap. 74), so as to prevent the flow of the tide above the city, and stop all navigation above the bridges," and "that a considerable expense for dredging might have been saved, if the natural flow of the tidal water had been properly directed."

Again, in speaking of the River Blyth and harbor of Southwold, it says: "As a general, although not universal principle, no cause has operated more extensively to injure the entrances of harbors throughout the United Kingdom, than excluding the tidal waters from lands below the level of high water, which served as natural reservoirs for the flood tide, and were the means of affording a valuable scouring power during the ebb. Nor does any subject more deserve the vigilant attention of your Majesty's Government, or of those intrusted with the conservancy of our harbors, than such encroachments, which are usually made quietly and gradually, and, when once completed, are difficult afterwards to remove.

"We have thought it right to enter into the above details, since Southwold is entirely dependent upon tidal waters for existence as a port, and since the value of the daily tidal scour in all our harbors does not seem to be sufficiently appreciated; nor can any case more strongly prove the duty of jealously guarding against similar encroachments."

And again in the case of Rye Harbor.

"For several miles round the town of Rye, and immediately adjacent to the harbor, there are large tracts of marsh land, a greater part of which are owned by proprietors residing in the neighborhood. Over a great portion of this plain the sea was formerly accustomed to flow at every tide, and thus formed a considerable back water, which operated as a scour to the harbor of Rye, and kept the channel open. The proprietors, however, uncontrolled by any guardian of the port, began by degrees to exclude the tide, and no steps being taken to restrain their encroachments, they obtained an Act of Parliament, erected dams and sluices across the river a short distance above the town, and finally excluded the tidal waters.

"By these means hundreds of acres of marsh have been reclaimed; while the harbor, deprived of its back waters, yielded to the mass of sand and shingle which rolled in with every wave, and which have now nearly obliterated the appearance of a channel.

"Three rivers drain this tract of country, and had there been no obstructions in their channels, they would have afforded an ample reservoir for tidal waters." (*Rennie's Rep.*)

The same Commissioners, in their second Report on tidal harbors, enumerate other instances equally important and instructive.

The harbor of Cork, for example, was injured by the "seven weirs that crossed the River Leed within one and a half miles of Cork; and again at Sligo, weirs exist which obstruct the upward flow of the tide."

And again at Belfast, "the lower lock of the Logan navigation is only one and a half miles above the town, and thus prevents the upward flow of the tide," to the injury of the harbor.

And again upon the Dee, "a weir or milldam, rising eleven feet above the bed of the river, exists just above the city, dams the water up for several miles, and prevents the upward flow of the tide;" and this is mentioned as one of the sources of the injury to the Dee.

And again Exeter is injured by the South Devon Railway, which has diminished the estuary and excluded the tidal water; and again at Newcastle, complaints are made of Newcastle Bridge, which, "with its narrow arches, heavy piers, and additional starling, acts almost as a milldam;" and again at Whitby, "a milldam which stops the upward flow of the tide, and a railway dam, recently made, which excludes 30,000 cubic yards of water on every spring tide," are referred to as a means of injury to the harbor.

And finally, at Yarmouth, "the narrowness of Yarmouth Bridge, and of the adjoining part of the haven," are spoken of as injurious to the harbor, because they act as a "great impediment to the flow of the tide."

We shall cite one more distinguished *authority*, — that of the Commissioners on the Tyne. In their summary report of May, 1859, they say: —

"It would appear probable that it is the daily ebb and flow of the waters from the sea that principally maintain undiminished the width and depth of that part which may be termed the estuary, and which regularly scours the channel within its reach; it is, therefore, of the greatest consequence to admit and properly direct the largest possible quantity of tidal water.

"Although *this is admitted by all whose opinion is of value*," &c.

It remains to be observed that the Commissioners on tidal harbors were invested with authority to call before them all persons from whom they could obtain information, suited to the purposes of the Commission, and to administer oaths to persons under examination; and that, in pursuance of this authority, they summoned the most distinguished engineers, both in the civil and public services; and especially those men (it is not worth while to enumerate their names) who have taken the most conspicuous part in the construction, improvement, preservation, and rescue of tidal harbors.

Even the least interested are aware that there have been some signal examples of successful engineering in the rivers and harbors of Great Britain during the present century; and it is very desirable that the principles by which this success was secured should be better understood. · Persons who speak with authority sometimes cite the examples of Havre and Dieppe, or of the Tyne, Clyde, &c., without, perhaps, a well-digested knowledge of the distinctive peculiarities of these harbors, of the objects of improvement, or of the modes in which those objects are accomplished.

It is upon the opinions of the distinguished and successful engineers referred to that the conclusions of the Commission, which we have quoted above, are based.

b — Reservation of the Mystic Pond Waters, and employment of Sluices, or Flood-gates. The observations contained in this branch of our subject are *partly* called forth by the following sentences in the *Report for supplying the City of Charlestown with pure water*: —

"Another and important advantage arising from the use of these sluices will be the ability to scour and keep clean the bed of the Mystic River, preventing the 'silting up' so common to all tidal rivers, thereby improving this stream for navigable purposes. Samples, on a large scale, of sluices, constructed expressly for sweeping away at low water the accumulating deposits, are found in the most important tidal harbors on the English and French coasts; and were it not for some effectual remedy of this kind, many of the most important would have been long since completely silted up." (pp. 35, 36.)

From the language here employed, taken in connection with some other sources of information, we learn that Dieppe, Havre, and similar ports, are the examples referred to in the *Report*.

We will take from M. Élie de Beaumont his concise and accurate description of the entrance of the valley of the Béthune at Dieppe.

On each side of the entrance of the Béthune which leads to the port of Dieppe, there are two cliffs of chalk, of considerable elevation.

The town is situated upon low ground protected by a natural sea-wall *(levèe de galet)*, which extends to the entrance of the port. The sea disturbs the stones of this wall, and tends to force them in a certain direction, which is most frequently that from West to East, because the prevailing winds are in this direction, and because the waves that break upon the shore in bad weather have in general a line of direction from West to East.

Hence arose the necessity for constructing very solid jetties, which project beyond the sea-wall, for the purpose of preventing the stones from filling the entrance of the port.

Notwithstanding this protection, the shingle sometimes gets by the jetty, and fills up the entrance. No better means of freeing a channel has been discovered than that of keeping back, by means of a basin, the waters of the river swollen by the tide. The gates are opened at low water, and a very rapid current *(une Chasse)* flows out, which carries a part of the shingle into the sea.

This means is employed in many ports, liable to similar obstructions: it is very expensive, and is a proof of the greatness of those natural forces with which the engineers have to contend in order to keep the entrance of such harbors in a practicable state.

M. Bailleul, in the beginning of his memoir on the port of Havre (1838), says: The port of Havre is assailed by two powerful enemies, the débris (shingle) of cliffs (on the sea-coast of Normandy between Etretat and Havre) and the silt (alluvium) of the Seine, which combine in their efforts to block up the port, and will succeed in doing it if a remedy is not soon applied.

It has been admitted, observes M. Lamblardie, in a remarkable memoir on the coasts of Haute-Normandie, published in Havre in 1789, that the coast suffers every year a loss by degradation of about one foot throughout its whole extent.

If then we allow that the distance from Cape Antifer to Cape de la Hêve is 13.67 miles (25,000 metres), and that the mean height of the Cliffs exceeds one hundred and sixty feet, we shall find that we are below the truth in estimating at 523,200 cubic yards (400,000 cubic metres) the material of all sorts, sand, marl, and flint, which the sea carries annually into the little road up the entrance of the port, and to the shoals of the same.

These materials are placed at the disposal of the currents, which take them up from the feet of the cliffs in great quantities after thaws, heavy rains, and violent storms.

It was to remedy this evil that *écluses de chasse* (sluices) were resorted to at Havre (in connection with jetties), in the beginning of the last century. It was for the same purpose, and to meet the same difficulty, that the great *écluses de chasse* were constructed about 1780, in the ports of Dieppe, Saint Valery, and Freport (pp. 1, 2, 11, 12).

It is wholly unnecessary to enter into a detailed comparison in order to show that these descriptions of artificial ports, opening upon an external sea-coast, and exposed to obstruction at their entrance by coarse drift detached from neighboring cliffs in storms, and transported by currents and ocean waves, bear no resemblance whatever to the protected and secluded Mystic, pursuing its undisturbed course in its natural alluvial channel, and discharging its waters into a sheltered bay.

But the above quotations from the Report contain what we conceive to be misconceptions upon the subject of river improvements, which would be mischievous if carried into practice, and against the injurious consequences of which, the public mind should, if possible, be guarded.

A plan which includes violent and sudden changes is wholly opposed to the fundamental principle which lies at the bottom of all improvements of tidal rivers.

A letter addressed to one of our number by Mr. Charles L. Stevenson, civil engineer, and intended for the consultation of the Commission, furnishes us with the occasion for treating the reservation of the waters of the Mystic, and the use of sluices, in a more specific manner, and with special reference to the case in hand.

c — *Mr. Stevenson's view* is presented in the following extract from his letter: —

"If the fresh waters flowing from Mystic Pond be retained in the pond during such hours as recent investigations indicate that the tidal inflow up the river would be thereby increased by an amount nearly equal to the volume of the fresh water yield, or as much less as may be found most advisable, a sufficient amount of water for Charlestown or Chelsea may be diverted, *and the balance of retained fresh water thrown in in aid of the increased tidal waters at such time of the ebb as experience and investigation show it to be of most benefit to the river, this will admit of as complete, if not better and surer scouring action than at present.*

"In the making a tidal reservoir of that space, now occupied by the fresh-water flow from the pond, may we not so far imitate nature in the action observable in tidal reservoirs as to expect like results? Let us suppose Mystic Pond raised, as proposed for the 'High Level,' (*Vide* Water Report, B. & S.) or some six feet higher than at present, with a dam at its outlet near Weir Bridge, so as to make it a fresh-water reservoir. The average fresh-water yield of the pond in 1859 was estimated at 23¼ million gallons per day; when acting as a storage reservoir we may safely assume the available yield at all times to equal twenty million gallons, or ten million for each tide. The maximum amount of water required for Charlestown and Chelsea, estimating for 100,000 persons, is six million gallons per day, or three million for twelve hours; this leaves some seven million gallons *with six feet head available to increase the tidal flow down the river at every ebb.* If we suppose the flow from Mystic Pond stopped, so that none of the water flowing therefrom remains in the bed of the river, above the estuary, at the commencement of flood at that point, the tidal flow up the river will be increased by an amount equal to the retained fresh water; or, taking a similar tide to that of Oct. 3, as an example, some nine million gallons more of tidal water would have passed into the river at each tide. *Having some seven million gallons of water in addition to this, under control, with a head of six feet, it would seem that the proposed erections, so far from being detrimental, would enable us much more completely to conserve the channel, as far, at least, as the head of the estuary, as the loss now due to the meeting of the flood and ebb currents is avoided, while we have it in our power to increase the velocity of the ebb, and the quantity of water that is of value, if at any time desirable.*"

The italics in the preceding extract from Mr. Stevenson's paper are our own. We have employed them to distinguish to the eye of the reader, the passages to which we desire to call his particular attention. Mr. Stevenson's letter is to be found in the Appendix.

The substitution of an artificial dam in the place of the natural dam, and above the latter, is in itself not only admissible, argues Mr. Stevenson, but even desirable for the maintenance and improvement of the river bed, apart from other considerations. The artificial dam will serve an economical purpose, and the loss of the water taken for daily use will be more than supplied by the increased range given to the tide of flood; but this last is not the question we are discussing. The question we are discussing is the benefit to be conferred upon the bed of the Mystic River, and by transmission upon Boston Harbor, by the judicious employment of flood-gates or sluices at the outlet of Mystic Pond.

We make this distinction, not for the purpose of adding anything to the clearness of Mr. Stevenson's statement, but in order to define the limit of application of a few of the thoughts that are suggested by the perusal of his paper, and presented here.

Let us inquire into the effects likely to follow from a reservation of the Mystic Pond waters, during the period of flood-current in the harbor, and the subsequent sluicing off during the ebb.

Since the increase of head in the Mystic Ponds that would result from a retention of the waters during six hours could not greatly exceed that now caused by the rise of the tide, we may safely assume that the average flow of the water discharged during the ebb would be about a mean of the rates observed at those points in the river at which the stream now pursues its natural course.

	Miles per hour.
The mean velocity of downward current at Wood's Mill Station was found to be about - - - - - -	1.30
At Herring Weir - - - - -	1.00
At Ten Hills - - - - - - -	0.60
At Station in Estuary of Mystic River (one mile above Charlestown Dry Dock) -	0.44

The average of these is 0.83 miles per hour. The total distance between the extreme stations of our list exceeds six miles. From this estimate of the rate of travel for the Mystic Pond waters, it appears evident that under ordinary circumstances, no portion of their scouring power can be transmitted to the lower part of the Mystic River during the entire fall of the tide; but that the greater portion of the water released by raising the gates at the time proposed, must, long before it reaches the harbor, conflict with the incoming flood current. Again; if by constructing a dam at the outlet of the ponds, the excess of rain-falls of the winter months could be stored up, so that a general increase over the present head of water could be insured for the entire year, no considerable quickening of the current at the *Estuary* would occur during the period of letting off. We have shown in the first part of this Report that the great increase of the sectional area in the lower portions of the river, as contrasted with the contracted and shallow channel above, causes a very great exhaustion of the power of the waters of Mystic Pond before they reach the place where this power can be most useful. The fresh-water current slackens so suddenly on reaching the broader and deeper waters, that even were the surface of the Mystic Pond six or ten feet above its present level, we doubt if, when suddenly discharged, it would augment the velocity of the ebb current in the Estuary more than two tenths of a mile. The Mystic Ponds are too distant to be made very useful as sluicing reservoirs while the channel connecting them with the sea is so very tortuous and shallow.

There is one circumstance connected with the use of sluices which has always been found highly unfavorable; it is this, that the greatest expenditure of power is in the immediate neighborhood of the sluice-way; and in the case of the Mystic, the scour would be mostly expended upon a bed of gravel and stones, which it would no doubt sweep down the river until these materials reached the deeper, and consequently more important portions of the stream, where the current, abating its force, would relinquish them. Even now this process may be seen at the periods of freshet, the gravel and stones are rolled along the bed of the stream, and at last come to rest, forming ridges, or bars.

We hold that, as far as possible, a uniformity of motion in a stream should be preserved; and that, if power is to be artificially communicated, its operation should be suited to give a moderate velocity to a great mass of water, rather than to convert small streams into torrents.

In the useful action of inland waters for the maintenance of harbors, it is not a necessary condition that the river stream shall flow from the interior to the sea during a single ebb tide, or in a single day, but simply that there shall be a seaward gain in the resultant motion given to earthy particles by the abrasion of the water, and that a sufficient mass of water shall be set in motion to prevent an abrupt exhaustion of power on reaching the sea. It is a remarkable fact that some of the most rapid rivers have the shallowest bars at their embouchures. The immediate loss of head, and enlargement of section, which a mountain stream experiences on reaching the sea renders it powerless to bear forward into deep waters the gravel and sand which its previous strength has enabled it so easily to sweep down from the uplands. *It is not by sudden violence that Nature executes her best offices, but by persistence in gentle efforts.*

What we have said concerning sluices in the two last sections, whether general or special, may very properly be brought to a termination by citing the judgment of Mr. G. R. Runnel as to their real utility.

"The history of such ports as Dover, Folkestone, Newhaven, Fécamp, Brighton, Dieppe, Havre, and Ostend, demonstrates the inefficiency of sluices.

"In the French ports, so strongly does the conviction of the inutility of sluicing prevail, that the engineers have almost entirely abandoned it." (*Rud. of Hydraulic Engineering*, pp. 88, 89.)

d — Mystic Pond, as a Reservoir. In the second Report on Boston Harbor, which we have recently transmitted to you, we pointed out some changes of vital importance that had taken place in the reservoirs, and promised that when all our materials were collected and digested, we would endeavor to designate the precautions necessary to guard against similar encroachments in future. It was not our intention then, neither is it now, to express an unavailing regret that so large a quantity of the tidal marshes and mud lands should have been filled during the present century. This operation was the concomitant of the growth of the city; and indeed, to a certain extent, the very mode of its prosperity and increase.

The political economists of the day would not have hesitated to sanction and encourage the schemes of enterprising and sagacious projectors, even if they had foreseen that one of their results would be the loss of water capacity in the harbor. Their part was to lay the foundations of commercial greatness; the duty devolved upon us is to maintain and improve the instruments of commerce; and with prudent measures, it will always be possible to secure to the port of Boston its present reputation of being one of the safest and most commodious harbors in the world.

Of these prudent measures, one of the most obvious, and least difficult, is the improvement of old, or the formation of new, tidal reservoirs. Now Mystic Pond, if opened to the free ingress of the tide, would prove a most valuable source of power; the currents of the harbor would then be quickened, their domain extended seaward, and Mystic River converted into a navigable arm of the sea.

In the central portions of the harbor, the tidal currents have peculiar values as positive scouring agents, for here the flood and ebb drifts do not traverse a common path, as in the narrow reaches of the Mystic River, and therefore cannot cancel each other's efforts. The islands divide the currents into different streams, and in such a manner that the ebbs and floods are not reciprocals of each other. The forms of the islands are very irregular, their outer or seaward shores lie at different angles, and present different outlines from those on the inside; so that the flood and ebb currents, impinging upon these obstacles, do not suffer similar deflections or interferences, and are, therefore, compelled to pursue independent paths. The fine channels on either side of the Lower Middle, examined during the past season, offer excellent illustrations of the benefits that may result from the conditions to which we have referred. Of these two channels, that lying to the southward of the rocky shoal is maintained by the *ebb*, which predominates greatly over the flood in scouring power; while the channel to the northward is the work of the *flood*, the strong and steady action of which presents a marked contrast to the feeble and irregular motion of the ebb. These effects are clearly traceable to the alternating influences of several islands upon the courses of the tidal streams.

Boston Harbor owes to its numerous islands, not only its sheltered and secure anchorages, but many of its deep and spacious channels. To the destruction of Bird Island, and the consequent changes in the directions of the currents, can be traced the accumulation of certain shoals, as we may show in a future report, when the Physical Survey of the harbor is completed. But let us resume our investigation.

The bottom of Mystic Pond lies below the bed of Broad Sound Channel; it would be itself a spacious harbor, and is admirably sheltered. Upon Diagram *C*, a profile of the natural dam which separates this fine basin from the harbor may be seen. The portion lying above the 5.5 feet line on our diagram (mean low water of the harbor) is about two and a quarter miles in extent, and six and a half feet in maximum thickness. Were this barrier reduced by removing about two feet of the earth for a short distance, there is no doubt that the natural scour of the powerful ebb and flood streams would then become sufficient to complete the destruction of the dam. It would require, it is true, skilful engineering to prevent the natural forces from making a disadvantageous use of the matter removed; but all this could be controlled by proper care, and by slow degrees of progress.

With regard to the ebb and flood currents which would be induced in the narrow portion of Mystic River by the proposed cut, we may remark that they would not be so violent as a comparison of the present relations of water-heads might indicate; because, by giving a free course to the whole range of the tide *wave*, a portion of the difference of level occurring on either the rise or fall of the tide would be restored, and less current called into action.

We need not go far to illustrate this point. The South Bay, a basin of double the area of the Lower Mystic Pond, is drained and filled by the tides without creating currents of sufficient strength to occasion serious difficulties. The rise and fall of the tides is not necessarily accompanied by currents, for those are only called into action by the *delay* of the wave due to friction, &c. In channels of great depths the tide *wave* propagates itself with such rapidity, that the surface of the sea alters its position but slightly from the horizontal; gravity scarcely suffices to overcome the inertia, friction, and viscosity among the water particles.

Again, it may be asked, what change will take place in the height of Mystic Lower Pond if the river channel is deepened. We have many instances, on our coast, of lagoons communicating with the ocean by narrow inlets, and from observations of the Coast Survey it appears that they preserve nearly the same mean level as the ocean, notwithstanding the very great reduction of range the tide wave undergoes in passing into any of them. If we leave the land waters out of consideration, we may presume that, in order to preserve a natural equilibrium, the *outflow* and *inflow* of a lagoon should be equal. Now, since the velocities of currents vary with the square roots of the heads which engender them, it follows that an equality of ebb and flood currents, at the entrance of a lagoon, will be maintained when the mean water height of this basin is a plane which cuts the tide wave into two such portions that the sum of the square roots of hourly heights, measured from this plane during a tidal day, will be zero. On the open coast, the symmetrical figure of the tide wave is everywhere exactly bisected by the plane which we denominate the mean level of the sea.

The tide wave which passes through an inlet in a lagoon of very great extent is almost entirely lost. The Great South Bay, Long Island, is almost tideless; and at Fire Island Inlet, which connects this lagoon with the ocean, the slack-water epochs are half tidal, — that is, the surface of the inland basin lying nearly at the mean level of the sea, the water does not flow in from the ocean till the tide outside has risen about half its range; and the flood drift continues till the tide has fallen again to about the level of the lagoon, after which ebb commences. The maximum ebb and flood drifts occur nearly at times of high and low water.

Although, comparatively speaking, the Lower Mystic Pond can be transformed into but a small lagoon, there will be found some trace of the phenomena we have described. The tidal range will be less than in the harbor, and the current epochs will be a little later than those of the local tide.

It is true that a very great disturbance of the tide now takes place in the Mystic River, so that even the upper portion of the wave is disturbed; but it is believed that a sufficient deepening of the channel will restore, in a great degree, the normal form; or, at least, that different parts of the tide wave will then suffer corresponding changes, so that its positive and negative portions (considered with regard to the mean sea-level) may be counterparts of each other.

We may conclude, then, that the mean level of Mystic Lower Pond, if converted into a tidal reservoir, will be about the same as that of the sea, or from four to five feet lower than at present. A considerable rise and fall of the tide will take place, but not so great as that of the harbor.

$1.3 \sqrt{h}$ is the expression which now seems to represent the velocities of the current in the Upper Mystic River,—h being the head, and the constant 1.3 being computed from our observations. By estimating the hourly rise or fall of the pond with the tide of the harbor,—considering this to take place with the *wave propagation*, as well as by *flowing water*,—we cannot see that the average rate of the currents will exceed two miles per hour, or the maximum rate reach above three miles, in the narrower reaches of the channel. If the channel were to be so much enlarged as to allow the passage of a broad section of the tide wave, the level of the pond would rise and fall so nearly with that of the harbor as to occasion only very feeble currents.

If the improvement here proposed be only partially effected by deepening the channel to the level of the river bed at Herring Weir (a little more than four feet above mean low water of the harbor), the mean height at which the surface of the pond would stand would be about two feet below its present level. This estimate is made on the supposition that the bed of the channel will remain fixed, which, considering the increase of scour, is not probable.

The actions of tidal currents, when undisturbed by waves or other variable causes, is to equalize the depths of the bays and channels over which they have free range. *It is, then, of the highest importance to connect any basin with a harbor when the depth of the former exceeds that of the latter.*

e — Characteristics of the Mystic and certain other Ponds. The following particulars comprise the leading results of Mr. Mitchell's investigations.

The two Mystic Ponds do not differ greatly in form and depth in the character of their shores, or other features which would strike the casual observer; but our more intimate examinations have led us to the discovery of very important points of distinction. The two basins are separated by a very narrow, though shallow bar, which so perfectly divides their waters as to allow of a marked contrast of chemical and mechanical conditions. The Lower Pond, visited occasionally by the sea, has accumulated a quantity of saline and sulphurous matter, which impregnates the whole mass of water lying below a fixed plane; while the Upper Pond is essentially pure and homogeneous throughout. We should mention here that the existence of foul matter in the Lower Pond is stated in Baldwin and Stevenson's Water Report of 1857.

In Tables 5 and 6 will be found the results of experiments upon the temperatures, specific gravities, etc., of these ponds, and upon Diagram *E*, the same results plotted in curves. These experiments show that in the Lower Pond, at a certain depth from the surface, we pass very suddenly from a warm to a cold stratum, and less suddenly from a rare to a more dense body of water; while, for the upper pond, we have the usual circular variation in the conducted heat, and no considerable variation of specific gravity for different depths.

By the taste and smell, it was observed that in the Lower Pond the upper ten or fifteen feet stratum is fresh; below this, is a narrow belt of odorless salt water, and from a depth of 19¾ feet to bottom, is found the very foul matter to which we have referred. Our hydrometers detected the passage from the fresh to the salt, and from the salt to the foul water; but our thermometer gave nearly uniform temperatures for the first two strata.

That the experiments of September 1, given in Table 5, may not be understood to contradict this assertion, we must explain that for the trial made at twenty feet in depth, the deep-sea thermometer, being of some sixteen inches in length, actually rested with portions of its scale in different strata, so that an intermediate result was obtained accidentally.

We have drawn a broken line, connecting the results of this date, upon the Diagram, to indicate that the curve is doubtful.

Still further experiments were made to ascertain the precise limits of the stratum impregnated with sulphur, by suspending metallic bands from floats, and observing the chemical action during different periods of time. Copper bands plated on one side with silver, if allowed to remain suspended twenty-four hours, were found to be completely blackened on the copper side below a point of 19$\frac{9}{10}$ feet from the surface of the pond, and the line or limit of the sulphuret was sharply defined. When suspended for short periods, the bands showed a steady increase of the sulphuret as the distance below the initial plane increased.

For nearly all our experiments in the Lower Pond, the silver side of the band remained untarnished, but a single experiment made at the very bottom of the pond showed a decided effect upon both sides. Doubtless the galvanic action between the two metals affected our results, for on using thickly-plated wire, we observed that the silver became rapidly sulphuretted. Test tapes, prepared with acetate of lead, and lowered down, and at once drawn up, gave indication of the presence of sulphur. The mud on the bottom was found to be sulphurous only for a limited depth.

In the Upper Pond, all tests failed to reveal the presence of an undue degree of foreign matter in the water. On a single occasion, a piece of plated copper, after lying on the bottom, was found to be tarnished, but nothing impure was observed in the taste or smell of the water or underlying mud.

Spot, Cochituate, Spy, and Fresh Ponds, were examined, but in the last named only could any peculiarities be detected. In Fresh Pond, a stratum of water affecting mostly the silver side of our plated band was found holding an intermediate position, the surface and lowest strata being apparently quite pure. The hydrometer detected no marked changes of density for different depths, and the thermometer showed a uniformity of temperatures below a point near the surface.

In Mystic River, examinations of specific gravities showed a predominance of fresh water as low down as Medford Bridge. It was noticed at this place that the salt water inclined to press up along the bottom on the last of the flood, so that the water near the bed of the stream was found of greater density than that upon the surface. At the Boston and Maine Railroad Bridge, the conditions are more nearly those of the sea than of river water.

Our tables of specific gravities are reduced to the unit for 60° Fahrenheit, so that the surface waters of the ponds may increase their weights as the temperature descends. It is a fact familiarly known, that the maximum density of fresh water is reached at about 40°, and the aggregate change in the specific gravity of water between this and 60° is less than one thousandth; it is evident, therefore, from Table 5, that no interchange of water can take place between the different strata of Mystic Lower Pond; for even at the depth of eighteen feet, the density, as observed, is much greater than the maximum for the fresh water of the surface. In the Upper Pond, a circulation may gradually go on as the seasons change.

The winter temperatures of Mystic Ponds are given in Table 7, and upon Diagram *F.* These observations were made when the ponds had been frozen over nearly three weeks, and the covering of ice had become about eight inches in thickness.

We may remark of these observations that they indicate the *circulating process* for the Upper Pond, and the *conduction* of heat for the impure portion of the Lower Pond. The sudden change of temperature, as the point of observation passes from the pure to the foul water, is again exhibited by these observations, and at about the same depth as in summer.

In order to complete these investigations, and to procure, for the satisfaction of the City Government, important information, the following inquiries were submitted to the distinguished Rumford Professor in the Scientific School of Harvard University, Mr. Horsford.

1. The amount of saline and mineral matter in general as compared with standard pure water?

2. If an excess of certain ingredients is found, whence their source, — local, or from influx of the sea?

3. If from the sea, do the conditions indicate frequent or rare renewals of sea water ?

4. Are the muds strongly impregnated with mineral salts, or other substances, calculated to contaminate spring water long in contact with them?

His full and detailed reply to these inquiries will be found in the Appendix to this Report; we shall limit ourselves in its text to a quotation of the summary alone.

"The Upper Mystic Pond is throughout its depth an eminently pure and soft water.

"The Lower Mystic Pond water is sufficiently pure at the surface, and for a depth of some fifteen feet, to serve the purpose of domestic use.

"Beyond the depth of eighteen feet, the amount of saline matter is such as to impair the taste, and below twenty feet the presence of sulphurous compounds, offensive to the taste and smell, with increasing saline matter, renders it wholly unfit for use.

"The excess of saline matter is due to the inflow — not infiltration — of sea water, on the occasions of high tide,— how frequently, and in what quantity, hydrographic observations only can determine.

"The foregoing observations are quite in keeping with occasional and rare, rather than frequent supplies of sea water. The sulphurous body at depths below twenty feet, is not due to the decomposition of any mineral constituents in the earth or rock at the bottom or on the sides of the pond. It is not due to the mud at the bottom of the pond spontaneously decomposing in a pure fresh water.

"It is conceived, in part, to be extracted from the muds of Mystic River banks and flats, as the incoming tide flows over them and discharges into the pond; and in part to the reducing action of the organic matter at the bottom of the pond on the sulphates of the sea water with which these organic matters of the mud are saturated.

"The sea water flowing in at high water, by virtue of its superior specific gravity, flows to the lower depths of the pond, displacing the purer, lighter water. The saline water, from the bottom up, diminishes but little in density till a level of forty feet from the surface is attained; from this point up, the diffusion is nearly in inverse ratio to the depth.

"If the sea water were shut out, the law of diffusion would obviously require that in time all the excess of saline matter should be removed. The action of the inflowing current from the Upper Pond would facilitate this purification."

f — Recapitulation. Under the first head of this Report, we entered into an examination of the Mystic Ponds and River, in the course of which we introduced a summary of the observations made by Mr. Henry Mitchell, an assistant in the Coast Survey of the United States, upon the currents, tides, tidal currents, and tide wave of these waters.

Under the second head, we presented the results of this examination with reference to the estuary of the Mystic.

Under the third head, we explained the relation of the river and estuary, together with their affluents, to Boston Harbor.

The object of the investigation, thus far, to which we gave an orderly course, was to ascertain the connection existing between these several parts or places; and having established their interdependence, we found that it would be inexpedient to do anything which would permanently impair the usefulness of the Mystic Reservoir.

Under the last head of our Report, which, in the disposition of its separate topics, was unavoidably desultory, we treated the general importance of interior reservoirs to tidal harbors like Boston; pointed out the manner in which the Mystic Lower Pond might be improved, and be made to perform a valuable office to the lower channels; and combated the idea that a dam with flood-gates at the outlet of Mystic Pond, or across the Mystic River, could be beneficial, or, in fact, could be otherwise than detrimental to the channel below it.

Throughout the whole of our Report, we have distinguished, by putting them in italics, the conclusions resulting from the observations made in the field, and also those general views and fundamental principles already established by former observers, and common to the profession of engineering in tidal harbors.

It must be understood that the intelligent engineer has already arrived at the determination of certain fixed principles of conduct, by means of observations and experiments; observations and experiments which (in the progress of accumulated knowledge) have ripened into comprehensive generalizations, or into governing rules for further observations and experiments suited to local circumstances.

We have before observed, but it cannot be too often repeated, that among these fundamental principles, the one which holds the primary place consists in the improvement of the natural and existing state of things; making it the object to assist nature, and to use the laws of nature derived from study and observation, either by restraining or promoting her operations, in such a manner as will accomplish the object in view.

It has been wisely said, in another case, where man combines and disposes of the operation of natural laws, in order to modify or improve nature, that he employs the means which nature herself supplies; above that art which adds to nature is an art that nature makes.

And such has been the general scope and tenor of this Report. Our calculations and conclusions, the rules we have laid down, the principles we have enunciated, have been derived either from observations and experiments instituted for this purpose, or from observations and experiments made at other times and in other places belonging to the common treasury of knowledge. And further, we have taken into view not only immediate, but also distant effects and changes; regarding those that affect the prosperity of a future generation, as not less worthy of our attention than those that directly concern ourselves.

Our general conclusions are: —

1. That it would be inexpedient to make the "changes contemplated by the City of Charlestown, in the disposition and level of the water in Mystic Pond."

2. That Mystic Lower Pond may be converted into a reservoir with advantage to the channels of the river and harbor.

3. If the *upper* pond is cut off and converted to the use of the towns as proposed in the Report of the Engineers of the City of Charlestown, compensation should be made by such excavations as will secure free tidal flow into the *lower* pond.

We have the honor to be, very respectfully,
Your most obedient servants,

Jos. G. Totten, Bt. Brig. Gen.,
U. S. Engineers.

A. D. Bache,
Superintendent U. S. Coast Survey.

Charles Henry Davis,
Commander U. S. N. Supt. N. A.

To His Honor, F. W. Lincoln, Jr.,
Mayor of Boston.
And,
Jesse Holbrook, Esq.,
Alderman, and Chairman of Harbor Committee, Boston.

DIAGRAMS AND TABLES.

TABLES AND DIAGRAMS.

TABLES.

TABLE 1.

Mystic River.

STATION.	Dist. from Charlestown Navy Yard.	Height of river bed above m'n low water of Boston harbor.	Area of section at low water.	Area of section at high water.	Depth at low water of Oct. 3d.	Depth at high water of Oct. 3d.
	Miles.	Feet.	Sq. feet.	Sq. feet.	Feet.	Feet.
Charlestown Dry Dock	0	—24.7	27363	41545	24.8	34.2
Mystic River, 1 mile above Dry Dock	1	— 8.0	8003	24049	8.0	17.4
Boston and Maine R. R. Bridge	2½	— 5.2	869	17019	5.3	14.7
Ten Hills	3	— 5.3	676	4527	5.3	14.6
Medford Bridge	5	— 0.1	19	530	1.2	9.5
Near Herring Weir	6¾	+ 4.3	149	506	1.3	4.6
Near Wood's Mill	7¼	+ 6.6	76	430	0.7	2.8
Weir Bridge	7½	+ 5.1	63	74	3.5	4.0
Narrows of Mystic Pond	8	....	70	90	1.7	1.8

NOTE. The areas given above must not be regarded as those of the *moving* sections, which are always less than those of the channel.

TABLE 2.

Table of Hourly Changes of Tides and Currents in Mystic Ponds and River.

Time.	Charlestown Dry Dock.		Ten Hills		Medford Bridge.		Herring Weir.		Below Wood's Mill.		Weir Bridge.		Lower Mystic P'd at Niles's Boat House.		Mystic Pond at Narrows.		
H. M.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Hei't	Vel.	
	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.			Miles.	
7.00	5.56		6.05	— 0.05	7.03	— 1.68	11.64	— 1.00	12.83	— 1.36	14.17	— 0.97	14.58	Currents too feeble to be accurately measured.	......	— 0.50	Datum line 5.50 feet below mean low water of Boston Harbor.
	L. W. (5.54 feet) at $7^h\,11^m$		L. W. (5.65 feet) at $7^h\,36^m$														
8 00	6.36	+ 0.30	5.95	+ 0.05	6.63	— 1.54	11.64	— 1.00	12.83	— 1.36	14.15	— 0.97	14.52		......	— 0.50	
					L. W. (6.57 feet) at $8^h\,15^m$												
9.00	7.76	+ 0 40	7.40	+ 0 30	7.20	— 0.38	11.64	— 0.90	12.83	— 1.36	14.13	— 0.97	14.52		......	— 0.50	
10.00	9.56	+ 0.30	9.95	+ 0.40	8.82	+ 0.64	11 64	— 0.90	12.83	— 1.36	14.13	— 0.97	14.52		......	— 0.50	
11.00	11.41	+ 0.10	11.20	+ 0.30	10.86	+ 1.81	11.64	— 0.83	12.83	— 1.36	14.13	— 0.90	14.51		......	— 0.52	
12.00	13.81	+ 0.30	13.35	+ 0.30	13.05	+ 1.17	12.95	+ 0.30	12.86	— 1.20	14.13	— 0.90	14.51		......	— 0.62	
13.00	14.76	+ 0 10	14.80	+ 0.20	14.67	+ 0.97	14.55	+ 0.45	14.34	0.00	14.50	0.00	14.51		......	— 0.45	
	H. W. (14.90 ft.) at $13^h\,20^m$		H. W. (14.90 ft.) at $13^h\,24^m$		H. W. (14.94 ft.) at $13^h\,30^m$		H. W. at $13^h\,46^m$										
14.00	14.60	— 0.20	14 70	— 0.05	14.85	0.00	14.89	+ 0.15	14.92	+ 0.44	14.72	+ 1.40	14.60		......	+ 0.30	
									H. W. at $14^h\,02^m$				H. W. at $14^h\,45^m$				
15.00	13.31	— 0.35	13.30	— 0.20	13.44	— 1.17	13.93	— 0.60	14.28	— 0.39	14.52	0.00	14.63		......	0.00	

TABLE 2. (Continued.)

Time.	Charlestown Dry Dock.		Ten Hills.		Medford Bridge.		Herring Weir.		Below Wood's Mill.		Weir Bridge.		Lower Mystic P'd at Niles's Boat House.		Mystic Pond at Narrows.		
H. M.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Height.	Vel.	Hei't	Vel.	
	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.	Miles.	Feet.			Miles.	
16.00	11.51	— 0.45	11.55	— 0.45	11.92	— 1.89	12.80	— 0.83	13.30	— 0.83	14.22	— 0.91	14.61	Currents too feeble to be accurately meas.	....	— 0.85	Datum line 5.50 feet below mean low water of Boston Harbor.
17.00	9.61	— 0.58	9.90	— 0.55	10.25	— 1.72	11.64	— 0.97	12.89	— 1.30	14.18	— 0.97	14.60		....	— 0.60	
18.00	7.41	— 0.70	8.25	— 0.60	8.73	— 1.86	11.64	— 1.00	12.88	— 1.40	14.17	— 1.05	14.60		....	— 0.70	
19.00	5.70 L. W. at 19h 37m	— 0.65	6.60	— 0.60	7.48	— 1.94	11.64	— 1.00	12.87	— 1.40*	14.17	— 1.05	14.60		....	— 0.65	
20.00	5.50	0.00	5.55	— 0.20	6.73	— 1.42	11.64	— 1.00	12.87	— 1.38*	14.16	— 1.05	14.60		....	— 0.62	
Deepest part of chann'l bed.	Feet. 19.2	....	Feet. 0.2	....	Feet. ...5.4...	....	Feet. ..9.8...	....	Feet. .. 12.1 ..	....	Feet. ..10.6..	....	Feet. — 65.5		Feet. 13.	....	
Distances from Charlesto'n Dry Dock.	....	Miles. 3	....	Miles. ....5....	....	Miles. .. 6¾ ...	....	Miles. ...7¼ ...	....	Miles. .. 7½ ..	....	Miles. ....7¾....		Miles. ..8..	....		

Note. The tides of "Dry Dock," "Ten Hills," "Medford Bridge," "Wood's Mill," and "Lower Mystic Pond," were simultaneously observed on Oct. 3, 1860; the same is true of the currents of the second, third, and fourth of those stations; the other quantities of the above table have been supplied from corrected observations of other dates.

* Interpolated.

TABLE 3.

Tides and Currents of Mystic Pond and River.

Date.	STATION.	Tides.		Current turns.				After tide of Ch. D. D'k.				Durations of			
				Time of day.		Aft. loc'l tide.		Tides.		Currents.		Currents.		Slack.	
		H. Water.	L. Water.	Fl'd to ebb.	Ebb to fl'd.	Fl'd to ebb.	Ebb to fl'd.	H. Water.	L. Water.	Fl'd to ebb.	Ebb to fl'd.	Flood.	Ebb.	Between fld. and ebb.	Between ebb and flood.
1860		H. M.	H. M.	H. M.	H. M.	H. M.	H. M.	M.	H. M.	H. M.	H. M.	H. M.	H. M.	M.	M.
Aug. 28.	Dry Dock	9 37	15 42	9 25		— 0 12				— 0 12					
" "	Dry Dock	22 00		21 52	16 25		0 43			— 0 08	0 43	5 27	7 00	50	5
" 29	Dry Dock	10 27	4 17		4 58						0 41		7·06	43	15
" "	Dry Dock	22 45	16 35												
" 30	Dry Dock	11 10	5 02												
" "	Weir Bridge	11 53						43							
" 29	Mystic River (1 mile above Dry Dock)			22 17	17 20					— 0 28	0 45	4 57	7 42	79	24
" 30	Mystic River (1 mile above Dry Dock)			10 52	5 59					— 0 18	0 57	4 53		16	8
" 31	Dry Dock	11 50	5 37												
" "	Weir Bridge	12 30		13 20	11 34	50		40		1 30	5 57	1 46		01	01
" "	Narrows (Mystic Pond)			14 08	12 25					2 18	6 48	1 43		45	10
Sept. 1	Dry Dock	12 30	18 32												
" "	Ten Hills	12 38	lost	12 30	19 15	— 08		08		0	43	5 35?	6 45	11	10
" "	Herring Weir	12 56	16 45 to?	13 15	11 00	19		26		45	4 42	2 15		08	01
" 3	Dry Dock	13 25	7 15												
" "	Ten Hills	13 37	7 45					12	30						
" "	Wood's Mill	14 06		14 30	13 06	24		41		65		1 24		15	15
" 4	Dry Dock	14 00	7 46												
" "	Boston and Maine Railroad Bridge		20 12		20 51										04
" "	Ten Hills	14 00	8 08					0	22						
" "	Medford Bridge	14 15	8 45	14 35	9 32	20	47	15	59	20	47	5 03		05	02
" "	Wood's Mill	14 45		15 36	13 18	51		45		1 36	5 32	2 18		12	24
" 5	Dry Dock	2 15													
" "		14 35	8 21												
" "	Boston and Maine Railroad Bridge			2 20	8 54					05		5 29	6 34	40	12
" "				14 51						16	33	5 57		38	
" "	Medford Bridge	14 45	9 07					10	46						
Oct. 3.	Dry Dock	13 20	7 11												
" "	Ten Hills	13 21	7 31	13 50	7 45	29	14	01	20	30	34	6 05		20	15
" "	Medford Bridge	13 37	8 15	13 58	9 12	21	57	17	1 04	*38	2 01	4 46		08	01
" "	Wood's Mill	14 01		14 43	13 07	42		41		1 23	5 56	1 36		08	04

* Gauge above bridge. — not the same as above referred to.

TABLE 4.

General grouping of results from tidal and current observations of Mystic Pond and River.

STATIONS.	TIDES.			CURRENTS.					
		Delay of wave.		Delay after D. D'k tide.		Durations of			
								Sl'k water.	
	Distance.	High water.	Low water.	Turning from flood to ebb.	Turning from ebb to flood.	Flood.	Ebb.	At turning from flood to ebb.	At turning from ebb to flood.
	Miles.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.	h. m.
Charlestown Dry Dock	0	......	......	10	42	5 27	7 03	46	10
Mystic River (1 mile above dry dock)	1	......	......	23	51	4 55	7 42	48	16
Boston & Maine R. R. bridge	2½	......	......	10	33	5 43	6 34	64	08
Ten Hills	3	05	24	15	38	5 50	6 45	16	12
Medford Bridge	5	14	52	29	1 24	4 56	......	04	02
Herring Weir	6¾	26	......	45	4 42	2 15	......	03	01
Wood's Mill	7¼	42	......	1 20	5 44	1 46	......	10	15
Weir Bridge	7½	42*	......	1 30	5 57	1 46	......	01	01
Narrows	8	......	......	2 18	6 48	1 43	......	45	10

* Result from a single comparison.

TABLE 5.

Temperatures and Specific Gravities of Mystic Ponds.

LOWER POND.						UPPER POND.					
Date, 1860.	Time.	Depth.	Period of Immersion.	Temperature.	State of water.	Date, 1860.	Time.	Depth.	Period of Immersion.	Temperature.	State of water.
	h. m.	feet.	m.				h. m.	feet.	m.		
Sept. 1.	14 15	1	......	74°	Fresh.	Sept. 1.	18 15	1	10	78°	Fresh.
	15 10	10	10	73	"		18 25	10	10	73½	"
	15 00	20	10	66	Sulphur's and salt.		18 35	20	10	71	"
	14 50	40	10	59	"		18 45	40	10	62½	"
	14 40	75	10	58	"		....	.....	.....	...	....

TABLE 6.

LOWER POND (Above the Shoal).							UPPER POND.					
Date. 1860.	Time.	Depth.	Period of Immersion.	Temper-ature.	Specific Gravity	State of Water.	Date. 1860.	Time.	Depth.	Temper-ature.	Specific Gravity.	State of Water.
	h. m.	ft.	m.					h. m.	ft.			
Sept. 10	15 05	1		64°	1.0004	Fresh.	Sept. 10	17 45	1	70°	0.9996	Fresh.
	15 25	18	10	64°	1.0031	Salt.		17 11	70	57°	1.0004	Fresh.
	16 12	22	8	60°	1.0055	Sulphurous and Salt.						
	16 30	50	8	61°	1.0031							

TABLE 7.

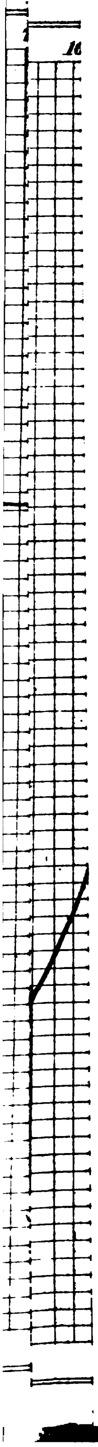
Winter Temperatures of Mystic Ponds, Jan. 2, 1861.

LOWER POND.				UPPER POND.			
Time.	Depth.	Temp.	Remarks.	Time.	Depth.	Temp.	Remarks.
h. m.	feet.			h. m.	feet.		
12	1	33°	A bleached cotton line, saturated with acetate of lead, detected sulphurous matter at 21–22 feet depth. The height of the water at Niles's boat house was 15 feet.	14.42	1	32¾°	
	2	33½			....	....	
	10	33½			10	34½	
	18	33½			....	....	
	19	33			....	....	
	19½	39½			....	....	
	21	42¾			....	....	
	24	42			30	36	
	40	42½			....	....	
	50	43			50	37½	
14	64	45		15.30	60 60	36½ 37½	First trial. Second trial.

For the above observations the period of immersion for the thermometer was, in each case, seven minutes.

At Weir Bridge, the stream flowing into the ponds (15h. 50m.) was found to be quite free from ice, with a temperature of 34°. The water was fresh.

HENRY MITCHELL, Asst. C. S., Observer.


1
16

APPENDIX.

MR. STEVENSON'S LETTER.

ENGINEER'S OFFICE, BUNKER HILL BANK BUILDING,
CHARLESTOWN, MASS., NOV. 22, 1860.

DEAR SIR: My absence at New York has prevented me from earlier complying with your request to place in writing the substance of my remarks, made to you a few days since, relative to Mystic Pond and River, explaining that the proposed constructions of the City of Charlestown to enable them to obtain a supply of pure water from this pond, in place of being detrimental to Mystic River and the Harbor of Boston, would rather be made to subserve the interests of both; or, in other words, that, by artificial erections controlling the flow into and from Mystic Pond, an amount of fresh water may be diverted for the use of the city, while the quantity of water of value as a scouring agent of the river is not diminished, but such agent can be made of greater value than at present.

From the facts adduced in recent careful and extended investigations made under the direction of your Commision, by Mr. Henry Mitchell, and with whom I had the pleasure of co-operating, we ascertain —

First, that Wood's Mill is about the limit of the tidal wave of the ocean in Mystic River.

Second, that Mystic Pond is not a tidal reservoir of present value to Boston Harbor.

Third, that owing to the elevation of the bed of Mystic River, north and west of Medford Bridge, above low-water mark of Boston Harbor, the fresh water from Mystic Pond continues to run ebb from five to six hours after the commencement of flood at the harbor; and the colliding of these currents, by checking the velocity of the flow, is detrimental to the tidal action on the bed of the river.

Your intimate knowledge of the details of the recent investigations renders unnecessary, on my part, much explanation of the reasons which lead us to the foregoing conclusions. The peculiar condition of

Mystic Lower Pond proves unequivocally the occasional admixture of sea water, but an examination of all the data presented shows that the limit of the wave up the river is at Wood's Mill. The average volume of the flood current into Mystic Pond, as found from observations, is one million cubic feet, or seven and a half million gallons, at every tide. Had the observations been continued for a longer period, or for a year, so as to bring into the account the neap tides, and the seasons when the height of the pond is such that no current can pass into it from the river, this average would doubtless be much less. While the volume of the flow into the pond is possibly of some little value to the *river*, the proportion which it bears to the average tidal inflow above Chelsea Bridge, less than $\frac{1}{320}$, is too small to allow of its effects being appreciable in the *harbor*, even were the pond not at so great a distance from the latter that its waters do not in one tide reach it.

The average duration of the ebb at Mystic Pond is 20 hours a day (or 10 hours for each tide), during which time the daily fresh-water yield, and the water flowed into the pond from the river, must pass out of the pond.

Now we find that of the ten hours of ebb, there are but about five hours during which the ebb current is unobstructed, the flood current colliding therewith during the remaining five hours. *The volume of water, then, which flows down during the first five hours of the ebb, is alone of value in acting as a scouring agent*, and that only in the upper reaches of the river.

It should be borne in mind that the time taken in passing from Wood's Mill to head of estuary, 4¼ miles, is 3¾ hours, as calculated from observations. Hence, there remains but 1¼ hours during which *water from Mystic Pond* passes below the head of the estuary. To reach Chelsea Bridge, 2½ miles further, assuming the maximum velocity observed at any time of ebb tide of October 3,—viz: six tenths of a mile per hour,—requires four hours ten minutes; or, in other words, *the tide would have turned to run flood at Chelsea Bridge some three hours before a drop of water from Mystic Pond could have reached Chelsea Bridge.*

Hence the conclusion that, as a tidal reservoir, Mystic Pond is not of present value to Boston Harbor.

As an exemplification of the colliding of the ebb and flood currents, let us take the tidal observations of October 3 (*vide* annexed plot of same). On this day the flood current commenced at the Navy Yard at 7^h 15^m A. M., while it continued to run ebb at Wood's Mill until 1^h 9^m P. M., a period of 5^h 54^m.

An average of observations made on board the schooner Bailey, and at the current stations, numbered 4, 6, and 7, at other dates than October 3, shows the duration of stand at flood at various points, as follows:—

Broad Sound — 7^m.

Tidal Station. No. 9 — Mystic River above Chelsea Bridge, 43^m; the day-tide stand being 58^m, the night, 28^m.

T. S. No. 8 — Above B. & M. R. R., 51^m; the day-tide stand being 1^h 23^m; the night, 40^m.

T. S. No. 7 — Head of Estuary above Ten Hills Farm, 19^m.

T. S. Nos. 6 and 4 — Medford Bridge and Wood's Mill, 9^m each.

If the fresh waters flowing from Mystic Pond be retained in the pond during such hours as recent investigations indicate that the tidal inflow up the river would be thereby increased by an amount nearly equal to the volume of the fresh-water yield, or as much less as may be found most advisable, a sufficient amount of water for Charlestown or Chelsea may be diverted, and the balance of retained fresh water thrown in in aid of the increased tidal waters at such time of the ebb as experience and investigation show it to be of most benefit to the river. This will admit of as complete, if not better and surer, scouring action than at present.

In the making a tidal reservoir of that space now occupied by the fresh-water flow from the pond, may we not so far imitate nature in the action observable in tidal reservoirs as to expect like results? Let us suppose Mystic Pond raised as proposed for the "high level" (*vide* Water Report, Baldwin & Stevenson), six feet higher than at present, with a dam at its outlet near Weir Bridge, so as to make it a fresh-water reservoir. The average fresh-water yield of the pond in 1859 was estimated at 23¼ million gallons per day; when acting as a storage reservoir, we may safely assume the available yield at all times to equal twenty million gallons, or ten million for each tide. The maximum amount of water required for Charlestown and Chelsea, estimating for 100,000 persons, is six million gallons per day, or three million for twelve hours; this leaves some seven million gallons, with six feet head available *to increase the tidal flow down the river at every ebb.* If we suppose the flow from Mystic Pond stopped so that none of the water flowing therefrom remains in the bed of the river above the estuary at the commencement of flood at that point, the tidal flow up the river will be increased by an amount equal to the retained fresh water; or taking a similar tide to that of October 3 as an example, some nine million gallons more of tidal water would have passed into the river at each tide. Having some seven million gallons of water in addition to this, under control, with a head of six feet, it would seem that the proposed erections, so far from being detrimental, would enable us much more completely to conserve the channel, *as far, at least, as the head of the estuary*, as the loss now due to the meeting of the flood and ebb currents is avoided, while we have it in our power to increase the velocity of the ebb, and the quantity of water that is of value, if at any time desirable.

Very truly yours,

C. L. STEVENSON.

CAPT. C. H. DAVIS, *Cambridge.*

PROF. HORSFORD'S REPORT.

GEN. J. G. TOTTEN, *Pres. Boston Harbor Commission :*—

In reply to the inquiries submitted to me in Mr. Mitchell's letter of 9th of September last, I beg to submit the following Report:—

The inquiries were—

1. "The amount of saline and mineral matter in general as compared with standard pure water?"
2. "If an excess of certain ingredients is found, whence their source,—local, or from influx of the sea?"
3. "If from the sea, do the conditions indicate frequent or rare renewals of sea water?"
4. "Are the muds strongly impregnated with mineral salts or other substances, calculated to contaminate spring water long in contact with them?"

The communication of Mr. Mitchell was accompanied by a number of samples of water from the surface, and from various depths of the upper and lower Mystic Ponds, from Mystic River, and from different depths of Spy and Fresh Ponds. There was also submitted a suite of muds from the bottoms of these ponds, and from the mud flats and other points of the Mystic River, to which, and also to the supply of waters, additions were frequently made by Mr. Mitchell and Mr. Stevenson. There were also supplied samples of copper wire rope, and strips of silver-plated copper, that had been suspended in vertical position for various lengths of time in the above waters, to ascertain their action on these metals.

The accompanying schedules exhibit the results of the analytical examination of the above samples.

Schedule A gives the specific gravities and the relative amounts of saline and organic matters in 1,000 cubic centimetres of each of the several waters, together with the temperatures and depths of the waters as far as observed at the time they were taken, and the temperatures at which the specific gravities were determined.

Schedule B gives the taste, color, and sediments of the various waters.

Schedule C gives the relative amounts of inorganic and organic matters in the various muds, dried at a temperature of 212° F.

Schedule D gives the results of the examination of the waters and muds of different localities, in regard to the origin of the peculiar sulphurous taste and smell found in the deep water of the Lower Mystic Pond.

Schedule E gives the residue of samples of water from the Lower Mystic Pond, in vertical lines taken from holes through the ice, furnishing the data for the curves F. and G.

To enable me the more fully to comprehend the inquiries, I have twice visited the Pond, and examined the outlet on Mystic River as far as Charlestown, besides making an expedition to Fresh and Spy Ponds.

COMPARISON OF THE MYSTIC POND WATER WITH STANDARD PURE WATER.

The water which stands first in relative purity in the neighborhood of Boston is that of Lake Cochituate, from which Boston derives its supplies. Compared with this, Fresh Pond and Spy Pond waters, which are eminently soft and well suited to domestic use, have more than twice the amount of foreign matter. The Upper Mystic Pond water has nearly twice the measure of foreign matter that either Spy Pond or Fresh Pond water has, — and the surface of the Lower Mystic has nearly twice and a half times as much as the surface of the Upper Mystic. At a point above the bar, the amount is more than five times as great. From the surface down, the measure of mineral and vegetable matters increases until the amount is nearly twelve times as great as that at the surface.

Cochituate contains		0.0534	in 1000 parts.
Fresh Pond "	28 feet from surface,	0.1076	" " "
Spy Pond "	25 " " "	0.1056	" " "
Upper Mystic "	surface,	0.2026	" " "
Lower Mystic "	"	0.4804	" " "
" "	" upon bar,	1.0354	
" "	18 feet from surface,	6.4996	
" "	22 " " "	9.4558	
" "	40 " " "	12.6806	
" "	70 " " "	13.6120	

Notwithstanding this considerable increase over the Cochituate, and Fresh, and Spy Pond waters, on comparison with the following standard waters, the result will be seen to be not unfavorable.

Croton water contains, in 1,000 parts,	0.4350
Fairmount " " " "	0.6014

The relative amounts of inorganic and organic matters are perhaps not quite so favorable, as the following table will show.

	Inorganic Residue.	Organic Residue.
Cochituate - - - - -	77.16	22.84
Fresh Pond - - - -	66.92	33.08
Spy Pond - - - - -	65.35	34.65
Croton - - - - - -	31.21	68.79
Fairmount - - - - -	65.69	34.31
Upper Mystic (surface) - -	71.28	28.72
Lower Mystic (") - -	75.69	24.31
" " (" above bar)	77.60	22.40

There is not, however, an amount of mineral matter that would deprive the surface water of the qualities of sweetness and softness. This is true of the Upper Pond, and of the surface of the Lower Pond. From the surface down, the total and relative amounts of mineral matter increase, and as two of the constituents of the water, the salt of lime and the salt of magnesia, decompose soluble soaps, forming insoluble lime and magnesia soaps, the water at moderate depths is unsuitable for the laundry.

The accompanying curve F exhibits the increase in saline matters from the surface down; and the curve G the total amount of residue, inorganic and organic. K exhibits the saline matter in the Upper Pond. The curve I, plotted from Mr. Mitchell's observations, given in Table 7 of the Report of the Boston Harbor Commission, exhibits the relations of the winter temperatures (they were made January 2, 1861) to the amount of saline matter at the different depths. The curve J, from the same source, enforces the illustration by exhibiting the temperatures at various depths of the Upper Pond at the same date.

The water of the Lower Pond, twenty feet from the surface, possesses, in addition to a brackish taste, a sulphurous smell and taste, and these peculiarities become more and more offensive at greater depths down to the bottom. At depths above forty feet, the water which is quite transparent when drawn, after standing a few days, parts with the offensive smell and taste, but without losing, in any degree, its transparency. At a depth of seventy feet, water also clear when drawn, after a few days' exposure to the air, loses its highly offensive sulphurous smell and taste, and at the same time becomes cloudy from the separation of sulphur. The upper limit of this sulphurous stratum in two localities especially observed, was very precisely nineteen feet and nine inches from the surface. At this point it is little more than perceptible, but increases in intensity of offensiveness downward, as the above statement in regard to the separation of sulphur shows. It was noted to be at about twenty feet in several other localities. At eighteen feet, the offensive smell and taste were not perceptible. At twenty-five feet, although the smell was perceptible on the day of collection, it was not recognizable two days after, nor could a reaction for a volatile sulphurous compound be obtained; while from a depth of sixty-two feet, it was readily perceptible to the senses for several days, and gave a prompt and decided chemical reaction.

The sulphurous body, which, at first thought, one would conceive to be either hydro-sulphuric acid or a volatile sulphide, as of ammonium, failed to give any precipitate, either with acetate of lead or perchloride of mercury, which, in the presence of abundant chlorides, is a better reagent. But on boiling the water with a mineral acid, and collecting the distillate, it gave a prompt black precipitate with sugar of lead, — a proof that there was present a complex compound which the mineral acid and heat decomposed, producing hydro-sulphuric acid.

The curve H exhibits the relative amounts of sulphide of lead formed from equal volumes of water at the depths indicated, the quantity becoming inappreciable at a little more than twenty feet from the surface.

This sulphurous body readily acts on metals. A copper wire rope, vertically suspended, became, in the course of twelve hours, thickly coated with sulphide of copper up to within nineteen feet nine inches of the surface; and a strip of copper plated with silver on one side became coated from the same limit downward on the copper side, with brown sulphide, but the silver, except in two points indicated in the columns L and M, was left quite untarnished.

This capacity of the Lower Mystic Pond water to act on bright metal surfaces, is possessed to a less extent by Fresh and Spy Pond waters. Silver-copper strips were lowered in both these Ponds, two in each. The detailed results are given in Schedule D. In Fresh Pond, at a depth of twenty-nine and one half feet from the surface, the action on copper and silver is observable in four and a half hours. In twelve hours, it extends through a depth of seven feet, where the sulphide formed is deepest, and for two feet farther, where the action is less marked. Beyond this point, the silver and copper remain bright to within one foot of the bottom.

In Spy Pond, the action commences at a point about twenty feet from the surface, and in twelve hours the silver and copper were deeply tarnished through the next eight feet two inches, less so through the following two feet, and for the last two feet the metals remained bright in one locality. In another locality, the metals were bright for one foot three inches only from the bottom upward. It is a peculiarity not so readily explained, that both the silver and copper are here tarnished, while in the Lower Mystic it was the copper chiefly.

It is quite apparent, upon an inspection of the samples of exposed metals, that the corroding agent is much less vigorous in Fresh and Spy Ponds than in the Lower Mystic. In the deeper parts of Cochituate Lake, no such stratum of sulphurous water has been observed. The consideration of the conditions in which these ponds differ from each other, leads to the second inquiry, to wit:—

"*If an excess of certain ingredients is found, whence their source,—local, or from influx of the sea?*"

A detailed analysis of the water taken from the bottom of the Lower Mystic, made by Dr. Hayes and published in the recent Report of Messrs. Baldwin and Stevenson, gives the constituents of sea water in about the proportions in which they occur in the open sea. The amount of saline matter is, compared with sea water, only about as 1 to 2.56,—that is, it is of the constitution of sea water diluted with nearly *one* and *a half* times its volume of pure water.

The water of Cochituate Lake contains in general the same constituents that are found in Fresh Pond, Spy Pond, and the tributaries to the Upper Mystic. The waters of the last three, although containing each a larger percentage of mineral matter than the Cochituate, are, as already intimated, eminently pure.

It is only in the deeper water of the Lower Mystic that the excess of certain ingredients is found, to wit, of the constituents which, sufficiently concentrated, constitute sea water, and of a peculiar sulphurous compound which is quite a new feature in the ponds of a region of primitive geology.

Is the salt water due to springs? The fact that the water of the Upper Mystic lying in the same primitive basin is free from all excess of saline matter is against this supposition.

Two other modes of derivation have been suggested for the salt water, one by percolation through the soil from the Mystic River, and the other by inflow of salt water at high tide.

If the former were true, the neighboring wells in which the waters do not stand above the level of the tide, would be likely to be more or less impregnated with salt; but of this there has been no complaint.

It is moreover well known, that, on the point of Cape Cod, and in other similar localities, the wells sunk quite near the shore, in which the water rises and falls strictly with the tide, do not partake of the brackish character of sea water.

That percolation does not take place at the greater depths, may be inferred from the fact that it does not take place near the surface. The mud near the outlet,—at a depth of eight feet,—and which, if the sea water came through the soil bearing its offensive smell and taste, would contain sulphurous matters, was found to be entirely free from them.

There is against this mode of supply the well-known fact that in under drainage, where the tiles are but two or three feet below the surface, however much manure may have been spread on the soil above, the water that escapes is quite pure. In addition to all these considerations, there is the fact of the fully adequate agency in the supply of sea water at extreme high tide. On such occasions the sea water entering the pond through the outlet, by virtue of its greater specific gravity flows along the bed of the pond and takes its position at the bottom.

Here, by the law of diffusion, the salt water is diluted by rising into the purer water above.

Is the sulphurous compound due to sulphur springs at the bottom of the Pond? To answer this question, let us consider the source of the hydro-sulphuric acid of sulphur springs generally.

In the Pyrenees, where the sulphur springs have been more carefully investigated than perhaps those of any other region, the opinion entertained by chemists is that the sulphur is present as a sulphide of sodium, accompanied by a small amount of free hydro-sulphuric acid.

The source of this sulphide is doubtless to be found in reducing agencies, such as organic matter, acting on sulphates. The familiar case of the formation of iron pyrites in the body of a rat that fell into a solution of sulphate of iron, is in point. The observation by Bastick, that a spring water, containing gypsum in solution, on being agitated with a little ethereal oil, closely stoppered and set aside for three months, became saturated with hydro-sulphuric acid, while the ethereal oil disappeared, is a further illustration of the same point. Now in such a primitive region sulphates and organic matters, if not wanting in the rocks, are at least as likely to supply the upper as they are the lower pond with sulphurous compounds. And as the Upper Pond is absolutely wanting in sulphurous water at any depth, it is rendered eminently improbable that the sulphurous matters of the deeper parts of the lower pond are derived from the earth and rock below. There are, however, two considerations which are quite conclusive. All strictly sulphurous spring water is instantaneously blackened on the addition of acetate of lead, while the water from the bottom of the Lower Mystic is not blackened by this reagent. This experiment shows, as did the test with perchloride of mercury, that there is neither hydro-sulphuric acid nor sulphide of any alkaline base or earth present in the water. It is only on boiling the water with mineral acid, as already remarked, and testing the distillate, that proof of the presence of a sulphur compound is obtained. The second consideration is this, — that when the sediment at the bottom of the pond, where the offensive taste and smell prevail, is examined, the surface sediment is found to contain the sulphurous compound, while that from a depth of a few inches contains little or none of it.

This source set aside, there remains a probable one in the agency to which the excess of saline matters is ascribed, to wit, the sea water.

Now whether the total offensive smell and taste go in with the sea water, or a part only, or none of it; or whether the source of the offensive smell and taste is in the mud at the bottom of the Lower Pond, — it being assumed that the mud has been brought in by sea water, — are questions that have been severally raised and submitted to research.

The muds have been subjected to chemical and microscopic examination.

After leaching the mud of both the Upper and Lower Ponds with a view to washing out any and all soluble matters present, the residues were examined for any and all sulphur compounds. The invariable result was a negative one. There were none present.

Now, on the theory that the mud contained bodies which by slow chemical action was evolving soluble sulphurous compounds, after washing out any such compounds ready formed, the residue must contain the parent source from which the soluble bodies were produced. Finding no sulphur, was conclusive that all the sulphur at the bottom of the pond was already in solution, and a constituent of the sea water.

The muds from Medford Bridge, and from the mud flats above the Eastern Railroad Bridge, were found to contain the same sulphur body, chemically speaking, that was found in water from the bottom of the Lower Mystic Pond. That is, they yielded to water the taste and smell of the offensive water from the bottom of the pond, and the substance was not precipitated with acetate of lead.

Moreover, on distilling with sulphuric acid, the hydro-sulphuric acid reaction was instantly obtained from the distillate.

The relative amounts of organic and inorganic matter in the muds of the different localities, showed that the mud at Medford Bridge, and on the flats of Mystic River above the Eastern Railroad Bridge, contained a vastly greater proportion of inorganic matter — such as sand — than the muds from the bottom of the deeper parts of the Lower and Upper Mystic. In the shallow parts of the pond, as near Niles's Boat House, and out of the main current flowing through the pond, the proportion of sand is greater. Where vertical tubes were lowered into the mud in the deeper parts, that from the bottom of the tube, as might have been expected, contained uniformly a less proportion of organic matter. Near the outlet, where the tide and current of the pond met and the suspended matters naturally fell, the amount of organic matter was found to be greater than at any other point observed.

The microscopic examination of the muds, for which I am indebted to Mr. Moore, of the Scientific School, shows the mud from the deeper parts of the Lower Mystic Pond to contain the various forms of naviculæ, and other silicious shields and remains of infusoriæ, that abound in all the fresh waters in the neighborhood of Boston, besides what seemed to be granules from vegetable cells. Those of the Lower Mystic proved to be quite identical with those of the Upper Mystic Pond, except that the Upper contained a greater proportion of granules from vegetable cells. The surface and sub-sediments were much alike in both cases.

In the mud near the outlet of the Lower Mystic Pond there were numberless vegetable cells, and occasional living animalculæ. These had not been observed in the muds from the great depths of the Upper and Lower Ponds.

The mud, from twenty feet above Medford Bridge, contained not more than one fifth as many organic forms as the deeper pond mud. They are much less perfectly preserved, and the variety is much less.

The mud from the flats, above the Eastern Railroad Bridge, did not contain one thirtieth as many organic remains as the mud from the deeper parts of the Lower or Upper Pond; and the sub-sediment contained less than the surface mud. These organic remains were moreover very imperfectly preserved.

Fresh and Spy Pond muds differed from that of the Mystic in that the variety of forms, and the proportion of vegetable cells were greater. There were, besides, some distinct green plants; and all were very perfectly preserved.

As the mud of the Mystic River, just above the Medford Bridge and that from the flats above the Eastern Railroad Bridge, contain, relatively, very few organic remains, and these fragmentary, while the mud at the bottom of the deeper parts of the Lower Mystic abounds in organic remains, distinguished for the perfection of their forms, it is quite obvious that the mud of the latter locality is not derived from the two former.

It is further obvious, from the circumstance that the mud of the Upper Pond, which the tide water does not reach, contains the same remains in nearly the same relative proportions of ingredients that the Lower Pond does, that there is an adequate source of the mud in the pond itself.

As the mud of the neighborhood of Medford Bridge and the flats below, when agitated with water, yields an odor and taste identical to the senses and chemical tests with that of the offensive water of the Lower Mystic, it is obvious that whenever the water, that has flowed over and leached these muds, is by high tide carried into Mystic Pond, the substance of offensive taste and smell must go with it, and in time take its position in the deeper parts of the pond. The ultimate source of this sulphurous body in the mud is, in part, simply decaying organisms,—exuviæ, excrementitious matters, etc., and in part, doubtless, sulphates of sea water acted upon and reduced by the organic matters of the mud.

As the offensive body is not a sulphide of any alkali or alkaline earthy metal which sea water contains, or of ammonium, it might be doubted whether the simple reaction of the sulphates of sea water in the deeper Mystic Pond waters contributes in any considerable degree to its production.

It is conceivable, nevertheless, that the organic matters at the bottom of the pond in contact with the quiescent salt water should, as hey decay, more or less reduce the sulphates, and yield sulphurous products which, by some transformation with organic matters, assume the peculiar chemical properties of the offensive body that have been observed; so that a process analogous to that which takes place in the mud on the flats may be regarded as going forward at the bottom of the Lower Pond.

The advance portion of the tidal current, as high water approaches, steadily leaching the mud of the banks of the Mystic River, and accumulating the offensive extract till it reaches the pond, glides in along the bed, and by virtue of its specific gravity takes its position at the bottom. To these two sources the offensive matter must be ascribed; and not to the mud at the bottom of the Lower Mystic, or the soil below, or rock, as a source of sulphurous matters.

If we ascribe to a like origin the sulphurous matter in Fresh and

Spy Ponds as evidenced by the action on copper and silver, we have the amount of offensive matter in these ponds bearing something like the same relation to that in the Lower Mystic, which the facilities for the approach of tide water and the measure of offensive mud over which it flows, in the several cases, bear to each other.

There would seem to be spring water free from sulphurous matter coming up in Fresh and Spy Ponds, — keeping the lower portion of the metallic strips bright. But in the Lower Mystic there is no evidence of the existence of such springs.

The offensive body in the Lower Mystic, diluting with the purer water above, as it approaches the surface comes in contact with the oxygen in solution from the air, and is oxidized and destroyed.

Appearances indicate that the occasional supply of salt water, and the influx of fresh water from the Upper Pond and lateral tributaries, are about in equilibrio. With a chart of the pond, and sections of its depths, taken in connection with the chemical determinations already made, and a few additional determinations of the salt water that reaches the pond at high tide, it would not be difficult to ascertain the amount of salt water of a given strength now present in the pond.

The determination of the time required in which to supply this measure of saline matter would necessarily invite some hydrographic observations.

The last inquiry of the series, —"*Are the muds strongly impregnated with mineral salts or other substances calculated to contaminate spring water long in contact with them?*" has been answered incidentally in the discussion of the other points that have been raised.

SUMMARY.

The Upper Mystic Pond is, throughout its depth, an eminently pure and soft water.

The Lower Mystic Pond water is sufficiently pure at the surface, and for a depth of some fifteen feet, to serve the purposes of domestic use.

Beyond the depth of eighteen feet the amount of saline matter is such as to impair the taste, and below twenty feet the presence of sulphurous compounds, offensive to the taste and smell, with increasing saline matter, renders it wholly unfit for use.

The excess of saline matter is due to the inflow, not infiltration, of sea water on the occasions of high tide; how frequently, and in what quantity, hydrographic observations only can determine. The foregoing observations are quite in keeping with occasional and rare, rather than frequent, supplies of sea water.

The sulphurous body at depths below twenty feet is not due to the decomposition of any mineral constituents in the earth or rock at the bottom or on the sides of the pond. It is not due to the mud at the bottom of the pond spontaneously decomposing in a pure fresh water.

It is conceived, in part, to be extracted from the muds of Mystic River banks and flats, as the incoming tide flows over them and discharges into the pond; and in part, to the reducing action of the organic matter at the bottom of the pond on the sulphates of the sea water, with which these organic matters of the mud are saturated.

The sea water flowing in at high tide, by virtue of its superior specific gravity, flows to the lower depths of the pond, displacing the purer, lighter water. The saline water, from the bottom up, diminishes but little in density till a level of forty feet from the surface is attained; from this point up, for fifteen to twenty feet, the diffusion is nearly in inverse ratio to the depth, and for the last twenty feet the density lessens but little to the surface.

If the sea water were shut out, the law of diffusion would obviously require that, in time, all the excess of saline matter should be removed. The action of the inflowing current from the Upper Pond would facilitate this purification.

In closing this Report, I have great pleasure in referring to the care and accuracy with which the numerous determinations, made by my assistant, Mr. Charles Merrick, have been conducted.

Respectfully submitted,

E. N. HORSFORD, *Chemist.*

CAMBRIDGE, Nov. 5, 1860.

A

	Date.	Depth.	Temperature.	Specific Gravity.	At temperature.	C'bic centimetres taken.	Total residue.	Loss at red heat.	Per ct. of inorganic matter.	Per cent. organic matter.
Fresh Pond	Sept. 19,	Feet. 28	57°	1.00006	56°	1,000	0.1076	0.0356	66.92	33.08
Fresh Pond	Sept. 19,	40	53°	1.0001	53°.5	1,000	0.1126	0.0428	61.99	38.01
Spy Pond	Sept. 21,	25	64°	1.000	56°	1,000	0.1056	0.0366	65.35	34.65
Spy Pond	....	35	63°	1.0002	54°.5	1,000	0.1148	0.0468	59.24	40.76
Mystic Upper Pond	Sept. 10,	Surface.	......	1.00004	52°	......	......	......	......	......
Mystic Upper Pond	....	Surface.	......	......	......	1,000	0.2026	0.0582	71.28	28.72
Mystic Upper Pond	Sept. 10,	70	......	1.0005	50°.25	1,000	0.4748	0.1064	77.60	22.40
Mystic Lower Pond	Sept. 10,	Surface.	......	......	......	1,000	0.4804	0.1168	75.69	24.31
Mystic Lower Pond	....	Surface. Another point	......	1.00001	53°.5	......	......	......	......	......
Mystic Lower Pond	Sept. 10,	Surface. Above bar.	......	1.0008	53°.5	1,000	1.0354	0.2320	77.60	22.40
Mystic Lower Pond	....	18	......	1.0035	52°	1,000	6.4996	2.4960	61.91	38.09
Mystic Lower Pond, above bar	....	22	......	1.0061	50°.25	1,000	9.4558	2.1920	76.82	23.18
Mystic Lower Pond	Aug. 29,	40	......	1.0084	52°	1,000	12.6806	1.8794	85.18	14.82
Mystic Lower Pond	....	70	......	1.0162	53°.5	1,000	13.6120	2.2672	83.35	16.65
Mystic River at Medford Bridge after high water	Oct. 3,	One foot from bottom.	......	1.0002	52°	1,000	0.3040	0.0832	72.64	27.36
Mystic River at Medford Bridge after high water	Oct. 3,	Surface.	......	1.0002	53°.5	1,000	0.2820	0.0720	74.47	25.53
Mystic River at Medford Bridge at last of flood tide	Oct. 3,	One foot from bottom.	......	1.0071	52°	1,000	10.4656	1.7788	83.01	16.99
Mystic River at Medford Bridge at last of flood tide	Oct. 3,	Surface.	......	1.0054	52°	1,000	8.0934	1.1130	86.25	13.75
Cochituate Lake	....	Surface.	......	......	......	1,000	0.0584	0.0122	77.16	22.84

B

	Date.	Temperature.	Depth.	Taste.	Color.	Deposit.
Fresh Pond............	Sept. 19,	57°	Feet. 25	Faint vegetable infusion.	Slightly turbid from vegetable matters.	Light-green vegetable flakes.
Fresh Pond............	Sept. 19,	53°	40	Same as above, with faint bitter taste.	Settled pretty clear.	Few deep reddish-brown flakes.
Spy Pond..............	Sept. 21,	64°	25	Swamp water.	Settled clear.	Abundant deep reddish-brown flakes.
Spy Pond..............	Sept. 21,	63°	35	Swamp water.	Settled clear.	Very abundant ditto.
Mystic Upper Pond....	Sept. 10,	......	Surface,	Tasteless.	Pale amber.	No deposit.
Mystic Upper Pond....	Sept. 10,	......	70	Tasteless.	Pale amber.	Few brown flakes.
Mystic Lower Pond....	Sept. 10,	......	Surface above bar	Tasteless.	Pale amber.	No deposit.
Mystic Lower Pond....	Sept. 10,	......	18	Faintly brackish, but not sulphurous.	Pale amber, faintly greenish shade.	No deposit after month standing.
Mystic Lower Pond....	......	......	22	Faintly brackish and slightly sulphurous, lost taste and smell in close vessel in few days.	Same as last, but at no time separating sulphur.	No deposit after month standing.
Mystic Lower Pond....	......	......	25	Same as last.	Same as last.	No deposit after month standing.
Mystic Lower Pond....	......	......	40	More brackish and sulphurous.	Same as last.	No deposit after month standing.
Mystic Lower Pond....	......	......	70	More brackish and more offensively sulphurous to taste and smell. With time and occasional exposure to the air lost both taste and smell of sulphurous matter.	Clear at first, after few days cloudy from separation of sulphur, and then settles clear.	No deposit at first, but in time light deposit of sulphur.
Mystic River at M'dford Bridge after high water	Oct. 8,	......	Surface,	Tasteless.	Pale amber.	Little or no deposit.
			1 ft. from bottom,	Tasteless,	Pale amber.	Little or no deposit.
Mystic River at M'dford Bridge last of flood....	Oct. 8,	......	Surface,	Brackish.	Pale amber.	Little or no deposit.
			1 ft. from bottom,	Brackish.	Pale amber.	Little or no deposit.

C

	Date.	Depth.	Dried at 212° F.	After ignition	Lost by ignition.	Per cent. Inorganic.	Per ct. Organic
		Feet.					
Fresh Pond	......	40	0.1983	0.1439	0.0544	72.57	27.43
Upper Mystic Pond	......	55	0.0913	0.0672	0.0241	73.61	26.39
Upper Mystic Pond	......	75	0.6525	0.5585	0.0940	85.60	14.40
Upper Mystic Pond } (top)	......	75	0.1318	0.0808	0.0510	61.31	38.69
Vertical tube } (bottom)	......	75	0 1731	0.1175	0.0556	67.88	32.12
Lower Mystic Pond, near outlet soft water	......	8	0.3310	0.2980	0.0330	9.96	90.04
Lower Mystic Pond near Niles's Boat-house	......	6	0.5267	0.5173	0.0094	98.22	1.78
Lower Mystic Pond near Niles's Boat-house	......	12	0.7683	0.7510	0.0173	97.75	2.25
Lower Mystic Pond	......	18	0.4110	0.4018	0.0092	97.77	2.23
Lower Mystic Pond } (top)	......	30	0.0712	0.0538	0.0174	75.57	24.43
Vertical tube } (bottom)	......	..	0.0961	0.0727	0.0234	75 66	24.34
Lower Mystic Pond, above bar	......	52	0.0710	0.0450	0.0260	63.39	36.61
Vertical tube	......	..	0.1118	0.0796	0.0322	71.20	28.80
Lower Mystic Pond	......	85	0.3546	0.2883	0.0663	81.31	18.69
Mystic River, twenty feet above Medford Bridge	......	..	0.5668	0.5108	0.0560	90 12	9.88
Northerly side of Mystic River (top)	......	..	0.7152	0.6520	0.0632	91.17	8 83
Mud Flats above Eastern Railroad Bridge (bottom)	......	..	2.1858	2.0583	0.1275	94.08	5.92
Mud Flats above Eastern Railroad Bridge, second sample, (bottom)	......	..	0.5360	0.4994	0.0366	93.19	6.81

D

	Date.	Time.	No action from surface down for this number of feet.	Length deeply tarnished.	Length slightly tarnished.	Distance from bottom up not tarnished.	Metal acted on.
Fresh Pond........	Sept. 19,	4 hours.	29½	....	4 feet.	2 feet.	Copper less tarnished than silver.
Fresh Pond........	Sept. 19,	12 "	....	7 feet.	2 "	1 "	Both copper and silver alike tarnished.
Spy Pond..........	Sept. 21,	8 "	20 +	8½ "	2 "	1 ft. 8 in.	Copper less tarnished.
Spy Pond..........	Sept. 21,	12 "	....	8.2 in.	2 "	2 feet.	Copper and silver alike tarnished.
Upper Mystic Pond,	....	12 "	70	None.	None.	70 "	
Low'r Mystic Pond,	....	12 "	19.9	50.8 in.	None.	None.	Copper deeply, silver but slightly tarnished.
Low'r Mystic Pond,	....	12 "	19.9	50.8 in.	None.	None.	Copper wire rope very deeply corroded.

Lower Mystic. — The sulphur as sulphide of copper from the surface of four inches of the copper wire rope, gave of sulphate of Baryta 0.052 grammes.

Spy Pond. — The sulphur from about one and a half square inches surface of silvered copper gave of sulphate of Baryta 0.0082 grammes.

Fresh Pond gave from about the same surface of metal, sulphate of Baryta 0.00324 grammes.

The Lower Mystic copper rope presented a vastly greater extent of surface than the metallic strips in the other ponds, but how much greater it would be difficult to estimate.

Mud from the Mystic River Flats above Eastern Railroad Bridge, 12cc., gave, when boiled with sulphuric acid, and the distillate conducted into acetate of lead, a precipitate of sulphide of lead, equal 0.0378 grammes.

Mud from 70 feet depth in Mystic Lower Pond — vertical tube — gave, when boiled with sulphuric acid, and the distillate examined, — for the top mud, a sulphur reaction; for the bottom mud, no sulphur reaction.

Mud from 70 feet depth in the Upper Pond gave no reaction for sulphur, nor did the muds of the Lower Mystic above a depth of eighteen feet; nor did the muds of Spy Pond or Fresh Pond.

The columns L and M exhibit the action of the recently drawn water of the Lower Mystic at various depths on metallic plate, copper on one side and silver on the other, due to the sulphur compounds present. It will be remarked that the silver is discolored only at the bottom and at a depth of from 20 to 25 feet, while the copper is tarnished throughout below the depth of 20 feet. The waters were collected on the 29th of December, 1860, and a separate strip of copper, plated with silver on one side, placed in each sample.

E

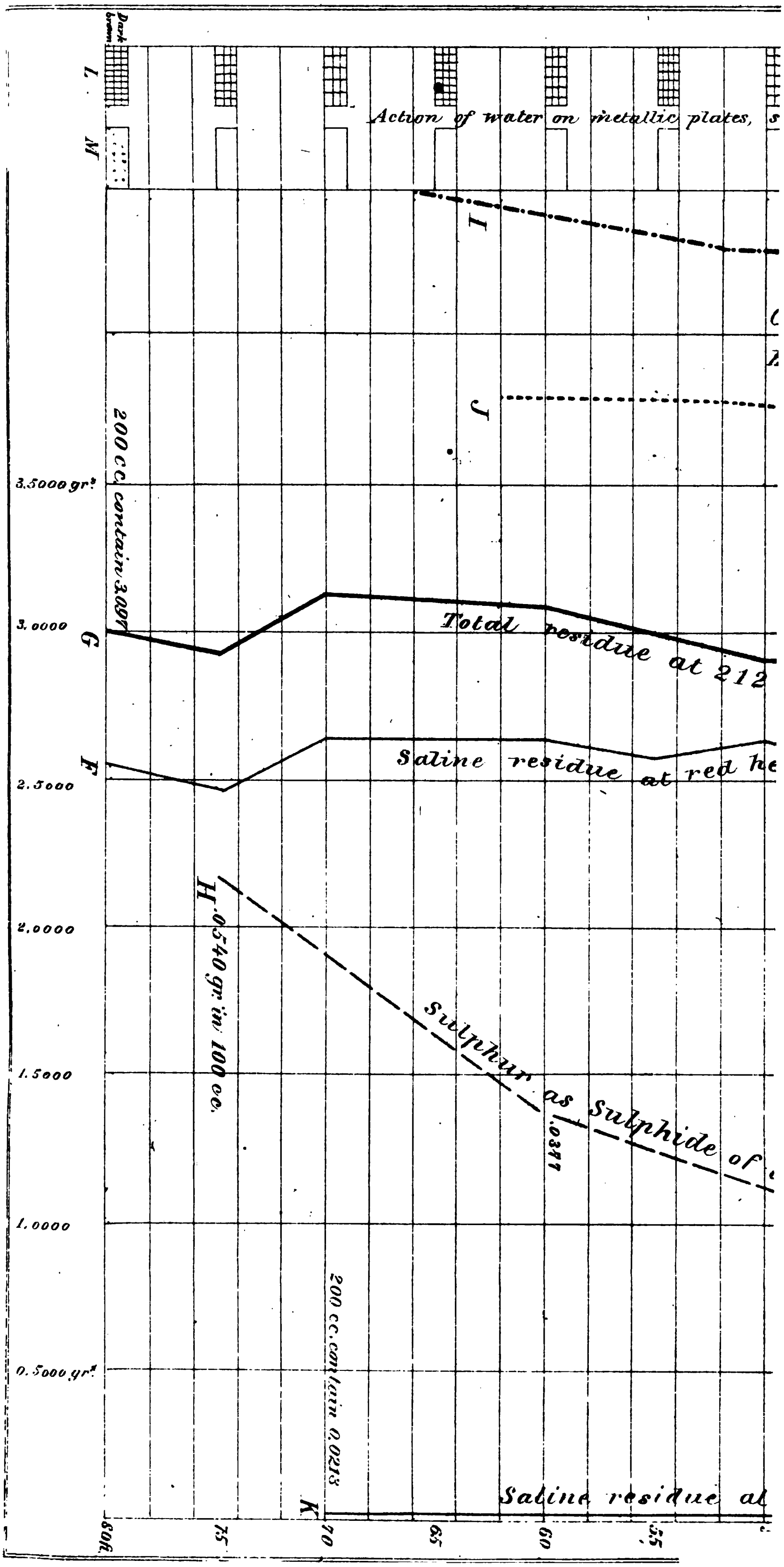
Determinations of residue from the Lower Mystic Pond water, taken at various depths, in two vertical lines from two holes cut through the ice: the one series where the depth was 80 feet, and the other where the depth was 55 feet. The quantity of water employed for each determination was 200 cc.

	First Series.			**Second Series.**			
Depth.	Total residue.	Inorganic matter.	Organic matter.	Total residue.	Inorganic matter.	Organic matter.	Remarks.
Surface,	0.0600	0.0300	0.0300	0.0600	0.0300	0.0300	Determination made only with second series.
5 feet,	0.0580	0.0335	0.0245	0.0580	0.0335	0.0245	
10 "	0.0523	0.0360	0.0163	0.0523	0.0360	0.0163	
15 "	0.0605	0.0299	0.0306	0.0610	0.0310	0.0300	
20 "	0.5412	0.4464	0.0948	1.0036	0.8294	0.1736	
25 "	2.1776	1.8923	0.2853	2.2400	1.9603	0.2797	
30 "	2.6513	2.2713	0.3800	2.5589	2.2204	0.3385	
35 "	2.6480	2.336	0.4144	2.6648	2.3952	0.3696	
40 "	....	....	....	2.8540	2.5090	0.3445	
45 "	2.9074	2.5410	0.3664	3.0049	2.5292	0.4757	
50 "	2.9384	2.6188	0.3196	3.2811	2.7423	0.5388	
55 "	3.0215	2.5716	0.4499	3.0263	2.5258	0.5005	
60 "	3.0793	2.6133	0.4660	....	....	....	
65 "	3.0989	2.6109	0.4880	....	....	....	
70 "	3.1283	2.6292	0.4991	....	....	....	
75 "	2.9358	2.4823	0.4535	....	....	....	
80 "	3.0974	2.5658	0.5316	....	....	....	

ERRATA.

Page 12, line 28, for "1.36," read "1.00."

Page 18, line 12, for "flood current," read "river current."


Dark brown
L
M
Action of water on metallic plates, s
I
J
200 cc. contain 3.097
3.5000 gr.
3.0000
G
Total residue at 212
F
2.5000
Saline residue at red he
H .0540 gr. in 100 cc.
2.0000
Sulphur as Sulphide of
.0377
1.5000
1.0000
200 cc. contain 0.0213
0.5000 gr.
K
Saline residue at
80 F.
75
70
65
60
55

City Document.—No. 62.

CITY OF BOSTON.

FOURTH REPORT

OF THE

UNITED STATES COMMISSIONERS

ON

BOSTON HARBOR.

In Board of Aldermen, October 14, 1861.

Laid on the table, and one thousand copies ordered to be printed.

Attest: S. F. McCLEARY, *City Clerk.*

J. E. Farwell & Co., City Printers, No. 32 Congress Street, Boston.

REPORT.

BOSTON, MASS., September 28, 1861.

HIS HONOR, J. M. WIGHTMAN, *Mayor of Boston, and Alderman* NEHEMIAH GIBSON, ESQ., *Chairman of the Joint Committee on Boston Harbor.*

GENTLEMEN: We call this our Fourth report, counting that on the Mystic Pond and River as the third; the latter, however, was a special report.

The subjects which we shall have the honor to bring to your notice, in the present report, have already been introduced in our First (Preliminary) and Second Reports. While we take pains to lay before you the results of our season's operations, whether they consist of surveys and maps, or of physical investigations, the graphic and tabular illustrations by which they are conveyed, or the general conclusions induced from them, we are equally anxious to preserve the connection between our several papers, and thus to explain the order in which our successive steps have been taken.

To do this, we shall begin by observing that the present Report, though it counts the Fourth in number, is the first of a series of Reports which will have for their special subject, the physical survey of the Inner and Outer Harbors of Boston, and for their final object, the improvement of these harbors. We have been aware, from the beginning of our labors, that we had before us a long and complicated undertaking, indispensable to the full understanding of our subject, and the only sure basis of action.

We hope to be able to point out the efficient means of repairing the losses already sustained, particularly in the Inner Harbor, and in the vicinity of the Narrows, and of preventing further injury. But to do this satisfactorily and conclusively, we must arrive at an accurate knowledge of the forces at work, and ascertain their resultants definitely. We must be prepared to submit our observations to the criticism of all who take an interest in our inquiries, and not only that, but to justify in their opinion our inductions and recommendations.

We will refer to pp. 5, 6, 7 of our Second Report, where we anticipated the necessity for continuing these observations through several seasons, and expressed our opinion of their importance. They still remain in the hands of Mr. H. Mitchell, Assistant in the Coast Survey, and we are indebted to him for the principal materials of this report. His labors are invaluable; they are not only marked by a spirit of honest and patient investigation in the field and the closet, but by a spirit of philosophical study, which enables him to turn those labors to the best account by the induction of general views and conclusions.

The parts of the harbor which have been under examination during the preceding season or that which is now closing are, —

South Boston Flats,
Bird Island,
Upper Middle,
Lower Middle,
Main Ship Channel, (Narrows,)
Charles River.

SOUTH BOSTON FLATS.

PHYSICAL CHARACTER.—South Boston Flats seem to have been formed in part by the waste of the land due to the action of waves, and in part by deposits from the rivers and sewers. The surface is a soft mud affording nourishment to a luxuriant growth of sea-grass; but below, at a depth of seven feet, (at Station 42, see Diagram A,) fine sand and blue clay were found, which may have been the antecedent soil, or possibly the deposit of rivers before the introduction of sewerage, or other foreign matter. Beneath the muds upon the outer border of the flats, a short distance to the northeast of Station 42, some underlying stones were detected by probing; these are supposed to form part of the group of shingle and gravel, which is misnamed "Slate Ledge."

The free growth of grass upon these flats, to which we have referred, forms a physical feature of some importance in our present inquiries; for we have noticed that certain requisite conditions are always indicated by it.

1. The soil must be fixed; the grass cannot take root where the currents or waves have sufficient power to agitate the sand.

2. The water must be shallow, because after a certain stage of its growth the grass requires air and light. Its buoyant leaves rise and fall with the tide, and attain sometimes a maximum length exceeding the entire tidal range, although on South Boston Flats the extreme length seems to be twelve feet.

3. The most luxuriant growths are found in districts where the water ebbs quite away at very rare periods.

It may be concluded, then, *that the presence of sea-grass indicates the absence or exhaustion of tidal drifts.* This grass does not appear until a certain stage is reached in the growth of a shoal or the waste of a beach. It plays an important part in the "constructive processes" of Nature, for it collects immense quantities of material, as the waters from rivers and sewers filter through its meshes. Not only does it retain the finer materials which are mechanically mixed with the water, but it not unfrequently arrests floating bodies also, holding them until they sink from becoming saturated or encumbered with the grass.

CURRENTS. — The numerical results from the current observations in the neighborhood of South Boston Flats will be found upon Table No. 1 — Stations 41 to 49. This table comprises nearly all the stations occupied during the year 1860, except those in the Mystic River, upon which we have before reported. We propose to discuss very few of the physical questions suggested by this table, in our present brief report, for the reason that it is still incomplete; we would however remark that it will be, when finished, the basis of all our arguments. It has been computed, thus far, from many thousand systematic observations.

The headings of our table explain sufficiently the nature of the results given in each column, although it might be well to add that the quantities entitled "Resultant Scouring Forces," are computed by composing all the hourly velocities for a tidal day, precisely as if these were forces acting simultaneously.

In order the better to illustrate these scouring forces, we have represented their magnitudes and directions, by arrows, upon Diagram A. In the Main Channel, off Long Wharf, the resultant forces take the direction of the ebb current, nearly; and on account of the abrupt increase in the width of the section, a rapid dispersion of the power takes place at a short distance to eastward. Near Long Wharf the scour takes a direction towards the flats, but is rapidly exhausted; while near East Boston the scour takes the direction of Bird Island. It may be seen that some of the material, borne along the bed of the stream from the Charles and Mystic Rivers, must find its way towards the border of the South Boston Flats. In the South Bay, at "Station 49," there is a great superficial scouring force, induced for the most part by land streams and sewer waters. This scour maintains channels of limited depth in this basin, but as it advances towards the harbor, it is entirely exhausted by dispersion before it reaches the main channel. The material it brings with it doubtless finds its way on to the borders of the flats. In this dispersion, the ebb from the South Bay, after passing the Central Railway Draw presses over upon the flats so strongly, that vessels are frequently swept out of the Fore Point Channel, and grounded.

Observations more recent than those given in our table, and which we have not yet found time to subject to strict classification, add incontestable proof of the presence of active causes tending to elevate the bottom on and beyond the northern border of the South Boston Flats. Here the submerged portion of the flat must receive supplies of material from the waste of more elevated districts, as well as from new deposits.

Both ebb and flood currents take direct parts in the process of washing the muds outward; and the resultant of all the forces of the tidal day has just sufficient power to roll forward very fine sand or other matter of like bulk and gravity, so that the increase, in course of time, may obtain some slight degree of firmness and stability.

Near the junction of the Fore Point and Main Channels, there occur eddies at certain stages of the tide which enclose regions of slack water, which favor deposits of sewerage, &c. Now slack water at any point may result from an absence of tidal activity, or from an opposition of forces; in the latter case — which is that of the locality of which we speak — the neutral region becomes a receptacle of the burdens of the contending streams, dropped as their powers slacken. This forced slack water lasts above an hour on each tide. Not only does the earlier ebb of the South Bay collide with the flood of the Main Channel for a brief period, but the united ebb streams from the Mystic and Charles Rivers are prone to pour around the city piers, and during the first quarter, meet the Fore Point stream in sharp conflict. One may observe at certain periods of the tides the punctual appearance of rips, marked, not alone by a tumult of the water, but by masses of miscellaneous floating matter which are drawn into the vortex.

The greatest velocity reached by the currents on the point of the flats, in twelve feet water, is scarcely four tenths of a mile per hour, a velocity inadequate to the removal, or even distribution of gravel ballast, and other material of this nature, which may be thrown over from the fleet at anchor.

The too sudden expansion of the ebb stream, (the compound of the Mystic and Charles River waters,) after passing the strait between the city and East Boston, is a grand source of mischief; for the power of this main stream is exhausted by the very act of divergence, and its margins collide with other streams which flow into the harbor by lateral channels. While upon the south side of the channel the resultant or scouring power of the main stream takes a southerly direction, we find upon the north side of the channel a reverse tendency, the resultant taking a northwardly direction, and adding accumulations beyond Bird Island. In the central region a neutral space exists upon the ebb, a point of exhaustation where the power is insufficient to remove any very heavy deposits that may occur, as the ashes cast down from steamers, &c. While, therefore, the natural forces seem busy with building up and extending the flats at certain points along the borders of the Main Channel, there is not enough scour in the thread of the stream to insure its remaining permanently free; very light material, river muds, &c., may be borne away, but the heavier class of deposits can but accumulate.

In the Fore Point Channel the scour is inconsiderable, and the power diminishes rapidly with the depth. The scour at Station 48 takes a direction opposed to that in the South Bay outlet, so that, in the present regimen of the channel, the elements of its destruction are at work. *It is our opinion that a proper structure on the flats would prevent the premature dispersion of the South Bay stream, and perhaps extend its power to the margin of the Main Channel.*

The structure referred to, which might be simply a quay wall, if extended round the northern portion of the flats, along the line or limit of scour, (see the determined portion of this line upon Diagram A,) would serve to prevent in part the dispersion of the currents in the Main Channel, which now occurs in this neighborhood. The basin or dock within this wall should be deepened in order that a portion of the tidal power, now superficial, might then reinforce the activity in the lowest water stratum of the channel.

It cannot be questioned that the volume of tide water, which flows over flats and shallow basins, is useful at distant points, although its tendency to increase the scouring power is not felt in the immediate vicinity.

Although our observations are not sufficiently numerous to demonstrate fully the truth of these statements, our results may be said to illustrate them distinctly.

1. The tendency of the South Boston Flats is rather to disperse and exhaust the tidal currents than to increase their power in the Main Channel of the Inner Harbor.

Referring to Table No. 1 we find that at station 43, opposite the flats, the ebb current, at its maximum, is less than at station 47, off East Boston. The reinforcement from the drainage of the flats has not compensated for the loss of acquired velocity which the stream has experienced on expanding its section.

2. The effects upon the currents of the channel, traceable to the influence of the flats, are, in the main, superficial. Upon tables 2, 3, 4, 5, and 6, we give selections from our observations at different depths along the channel, and upon Diagrams

B, C, D, E, and F, graphical illustrations of the same. If we compare the ebb current at these several stations we see that the ebb is strongest upon the surface at Station 47, but below this point at Stations 46, 43, and 38 (near the flats), the superficial stratum has lost a portion of its velocity by dispersion, while at certain depths below the level of the flats there has been no loss of power, but perhaps in some cases, by reason of contractions near the channel bed, even a gain in strength.

The effect upon the flood current we cannot so easily trace, on account of the influence of river water which resists the flow of a superficial stratum. This effect of the land waters is of course most conspicuous above the flats, at Station 47 (see Diagram E, and compare with B). In these diagrams we have connected the extremities of the arrows measuring the velocities for different depths, by dotted curves, in order that the changes in the positions of the axes or thread of motion might be the more conspicuous. In the experience of the Coast Survey observers, who have studied these questions at various points upon the coast, it has been uniformly found that *tides, flowing off from shallow flats, do not at once communicate their motions to the whole body of the water in the channel, but for a considerable distance, they affect only the superficial stratum, gradually, however, the motion of the mass becomes general* *and uniform.* River water especially, being specifically lighter than that of the sea, flows for a long distance over the latter as a superficial stream. The Hudson River, on reaching New York Harbor, becomes a superficial stream, but sixty miles beyond the Bar a general movement of the sea to the southeast is clearly traceable to the influence of land waters, and at this distant point, the observations at thirty fathoms depth, as well as the form of the bottom, indicate considerable scour.

In estimating the value of a river or shallow tidal basin as a source of power for the scour of channels, it is all important that we should consider its distance from the point where the work is required.

If the influence of the tidal prism, which covers South Boston Flats, is merely superficial in its tendency to quicken the currents of the Main Channel, its value is very small, for it is in this neighborhood that scour is most required. *If we desire to make a body of water useful at a very short distance, we must discharge it from a deep reservoir.*

Were our stations and observations sufficiently numerous, we could ascertain with great exactness the value of bodies of tide water covering the flats on either side of the main channel, and thus, reducing this question to mathematical demonstration, leave nothing to conjecture or uncertainty.

The currents which ebb and flow along the channel ways owe but little of their velocities to strictly local conditions; they fill and drain distant basins, and the *heads* which engender their velocities act from widely devious directions and at different epochs. Where tidal and river waters both occur, the question of flowage is rendered so complex that no *a priori* reasoning has yet been able to determine the velocity of the current from point to point, or to predict, with any degree of accuracy, whether smaller bodies of water adjacent to the channel, will, in any particular case, increase or diminish the channel flow. While, on the one hand, extended tracts of shallow waters impede the tide wave and consequently augment the tidal currents, they may cause, upon the other hand, an expansion and partial exhaustion of the river currents, and by offering greater friction as the section widens, diminish the acquired velocities of both tidal and river streams. The South Boston Flats no doubt increase the velocity of the tidal currents in the Lower Harbor, since they must be filled and drained for the most part by *running* water, the propagation of the tide *wave* over the shallow districts being necessarily much impeded.

We ought to remark here, that, although in Boston Harbor the scour of the principal channels is a function of both ebb and flood currents, it is the ebb which has usually the greater weight; and where the flow takes place from a shallow basin, the distance between the initial and the working point also enters into the function with a peculiar form. The ebb, although inclined to be superficial in harbors, is usually the stronger current, not only because it is reinforced by land waters, but also because it is itself concentrative. *It is especially noticeable in all shallow bays that the ebb is concentrative while the flood is dispersive.* Although the rise and the fall of the tide are reciprocals, the currents which they engender are dissimilar in character. Since the tide wave travels most rapidly in deep water, there is, on the fall, a sloping towards the channels from all directions, and consequently a flowing in towards certain main avenues. On the other hand, during the rise of the tide the water gains in height more rapidly in the channel, and a flow takes place from the deeper towards the more shallow water. We may assume then that the ebb has the greater mechanical power, for it is able by concentrating its forces to overcome the friction of sands, &c., and accomplish work to which the flood would be unequal.

Perhaps it might be urged that any tendency of the currents to deposit their burdens upon the flats is advantageous to the channels. In a future report, we shall show that the upper middle would have long ago been removed by the scour of the currents, (for it is a bed of brick-clay,) had it not been for the dispersion of the scouring forces to which we have referred; and we shall also be able to show that the augmentation of low-water flats, occasioned by the wasting of Bird Island, has increased dispersion so much as to allow of accumulations which now threaten the Main Channel itself.

It must, nevertheless, be borne in mind that in extending solid structures over the flats we deprive the harbor below of the benefit of a great section of the tidal prism, and the question whether the deepening of a certain portion will afford adequate compensation for this loss, is in some degree, as we have seen, dependent upon local conditions, and is only to be answered after the most careful observations.

BIRD ISLAND.

This island has been so wasted by the action of waves and currents, that it is now only visible after the tide has fallen one half its range. Its present relations to the hydrography of the harbor are very peculiar, for, by reason of the brief period of its submergence upon each tide, it is subject to great abrasion, but can furnish materials only in certain directions. Were the tidal and current epochs coincident, that is, if the currents turned precisely at times of high and low water, the action of the ebb and flood drifts over this island would be similar, and there would be little removal of rolling material; but in truth tidal and current epochs are rarely if ever concurrent, and, in the case of Bird Island, the ebb current, commencing before high water, washes its eastern and western extremities during the major part of the time of submergence, the flood only prevailing for a very brief period after the bank is covered.

We might generalize the conclusions at which we have arrived from a study of Bird Island, and say that, as a rule, *a half tide island or bank must undergo lateral extension*,—it must continue to waste until it sinks below the low-water plane. The islands of Boston Harbor are all wasting, and parts of each are already presenting the conditions here described.

It is true that in the case of Bird Island the currents have nearly exhausted the material over which they have immediate power; the absence of sand, the grains of which are below a certain size, is a striking feature of the more prominent parts of the island. We might, from a mere inspection of the material remaining, have determined the limit of the power at work almost as accurately as our observations have done. Our velocities indicate a power sufficient to roll *coarse sand;* we actually find *gravel* to be the smallest material left behind. At Ram's Head Spit, on the wasted portion of Lovel's Island, our observed velocities indicated resultant power sufficient to move *gravel*, we find in this locality nothing smaller than *shingle* remaining.

The ebb tidal current presses strongly upon Bird Island as its waters endeavor to escape by way of the northern channels. We cannot discover any considerable causes for accumulations between this bank and the Main Channel-way, although there are three feet of mud overlying hard sand in fourteen feet of water. There is, upon the most elevated point of Bird Island, a southerly scouring power exerted, which is due to a prevalence of the flood drift at that particular point, and it is true that the stagnation which prevails along the southern border of the bank during the entire period of flood, is favorable to accumulations for a time; yet so steady is the wear of the ebb drift that it would seem impossible for any deposits to become fixed.

The study of the forces in the neighborhood of the shoal spit, which extends southward from Bird Island, convinced us that this is not an accumulation of natural deposits, or at least that no elevation of the shallow portion can now be in progress. The scouring power, it is true, is weak at this point, but it is not exhausted, and its direction is nearly parallel to the scour in the Main Channel—the tendency must be to *waste*, not to *construct*. If this shoal were removed by dredging, or harrowed up, and suffered to wash off during the ebb current, we are convinced it would not reappear. The only way in which it seems to us the destruction of Bird Island is injuring the harbor, is the consequent increase of the width of the water-way and hence the weakening of the ebb scour by dispersion.

UPPER MIDDLE.

As we follow the Main Channel of the upper harbor we find it divided into three avenues by Governor's and Castle Islands, and it is at the point of division of the ebb streams that we find the shoalest portion of the channel. The Upper Middle is not an accumulation, but a ridge of the original blue clay which underlies the neighborhood of Boston; it has not been removed because the currents have not had adequate power. Were the three ebb streams compelled to continue in the same course this bank would give way slowly. The resultants of our current observations show that the chief loss of power is due to the draught through the channel northwest of Governor's Island.

Upon Diagram G we have plotted the resultants at the various stations in the neighborhood of the Upper and Lower Middles. The natural arrangement of the forces, it may be seen, favor the preservation of these banks, although in the case of the Upper Middle the strong ebb and flood drifts ought, it might be supposed, to dissolve little by little the aluminous earth which forms the channel bed. Probably the extreme hardness of the clay has resisted to a great extent the wear of the water. Again, the resultants of the tidal forces being exhausted, shells and other bodies of the rolling class have accidentally collected, and there being no power for their removal, have shielded the clay bed in some degree. We actually found such a covering to exist — a thin stratum of loose shells.

LOWER MIDDLE.

The Lower Middle is a shoal of a compound character; it has a rocky nucleus, it is a wasted island, and it is a neutral region between channels in which the prevailing drifts are relatively opposed in direction. The channel to the eastward of the shoal is sheltered from the ebb stream by Governor's Island, but is a direct track for the flood current. On the other hand, the channel to the westward of the bank is the more direct path of the ebb, and this is its prevailing drift. In any event a shoal would form between two channels thus contrasted, and we are not therefore surprised to find evidences of accumulations in some parts of this shoal, although in other portions the groups of boulders reveal the permanent character of the obstruction. It is very remarkable that this shoal is never traversed by strong drifts, although the currents are rapid in the channels upon either hand—here is another feature favoring accumulations. The stagnant character of the water covering this shoal might have been inferred from the luxuriant growth of sea-grass, which as we have previously announced, requires among other conditions, a certain limit of tidal action.

In the channels, on either side, the flood drifts are respectively 0.73 and 0.58 miles per hour, while between these localities, upon the bank itself, we note, by simultaneous observations, "very feeble horizontal movement." The ebb, in a similar manner, runs 0.26 and 1.18 for the channels, while the intermediate stations upon the shoal give us no measurable velocities.

MAIN SHIP CHANNEL. (NARROWS.)

Our numerous stations in this locality present us with singular results. At the extremities of this channel the water is scarcely agitated by currents, while the central portion is crossed by very strong tidal drifts which, however, accomplish no scour, for their resultant is *zero*—the forces are very strong but are in equilibrium. The encroachments upon this channel are evidently the effects of waves during storms; but if scouring forces were at work along the channel bed the destruction of this avenue would, to some extent, be stayed. The shutting up of Black

Rock Channel would deprive the Main Ship Channel of no advantage in point of currents, and would perhaps check the present injurious action of waves; it might cause such a change in the course of the currents as to introduce a scouring power into the Main Ship Channel; it would at least, render the navigation less troublesome, by removing cross drifts which now frequently sweep vessels from their course and cause them to go on shore.

That part of the flood stream, which runs along the north side of Brewster Bar, sets directly over Tower Rock, and thence it sweeps over among the rocks to eastward of George's Island, where it exhausts itself. A float, two feet in diameter, drawing twenty-two feet of water, which was suffered to drift through Black Rock Channel on the strength of the flood current, grounded and held fast upon Tower Rock —an object which is so small in circumference, that even with good ranges, one may find it only with great difficulty. That part of the Ship Channel in the immediate neighborhood of the Narrows Light is the scene of continual whirls and eddies, which, although not violent, are bewildering to the navigator. To vessels of great draught the navigation is rendered doubly critical from the close proximity of these whirls to Corwin and Tower Rocks. These whirls, to which we have given the closest study, are, in the main, due to the influence of the streams through the Black Rock Channel; their characteristic forms and their epochs will be made the subject of a special note in a future report.

CHARLES RIVER.

The chief characteristics of the estuary of the Charles River are sucessions of blind channels with shallow bulkheads. The causes of these sudden alternations of channels and banks are exceedingly simple. When the channel of a river is confined, and is of uniform width, the depth will be more or less the same from point to point, and this depth will be but little greater than that required for the conveyance of the inland supply — the equal tidal forces effecting little or no scour — but where a river terminates in an estuary, it frequently happens that the ebb and flood currents, entering at different angles, choose different paths, digging distinct trenches for considerable distances until a point is reached where the two paths concur, at which point they counteract each other's efforts, and a bulkhead is left. In the case of Charles River the flood and ebb have, at some points different paths, but the former conflicting with the river stream, leaves little or no trace of its power. The ebb on the other hand, when traversing a region where its path is distinct, effects in conjunction with the river waters, a considerable scour. Our observations reveal these simple operations in a manner remarkably distinct and conclusive. As an illustration, we give upon Diagram H the curves of velocities across the channel of the Charles River, off the foot of Mt. Vernon Street. It may be seen from this, that the volumes of ebb and flood do not differ widely, but the position of the axis of the flood is more central than that of the ebb. These curves illustrate the influence of the momenta in directing the course of tidal streams. There is no reason why the axes of the flood and ebb at this station should differ in position, except that they each preserve for a time the velocity and direction acquired in an earlier stage of the journey. Why, it might be asked, after an inspection of our diagram, are there not in all cases two channels, one lying along the axis of the ebb, the other following that of the flood? The answer is simple ; although the flood at a certain place may at maximum exceed in velocity the highest rate of the ebb, the duration of its flow is less, and consequently the *resultant* may be zero,. and no permanant scour be effected. The shallowness of the muddy bulkheads indicates a lack of inland scour, that is, a scanty supply of river water.

In the Charles River there occur indigenous oyster beds here and there — *usually near mid channel,* *and usually in ridges at right angles to the direction of the stream.*

The bridges over the Charles River are not arranged with suitable reference to the natural flow of the currents, and it frequently happens that the momenta of the streams are destroyed by encounters with the piers and piles of the bridges and adjacent wharves. There is reason to believe that the river current, in the absence of the bridges, would distribute its deposit gradually, as its velocity slackened in its progress towards the sea, instead of throwing it down in abrupt piles, as now. The ebb and flood tidal currents, approaching from nearly opposite directions, are differently deflected by the artificial structures, so as to complicate their relative paths and make it impossible to lay down a uniform rule for future structures in different portions of the estuary, as each case of a future structure must be a special one, and have relation to those already established in the neighborhood.

There are some localities where the building out of the river banks would improve the course of the stream, and there are other points where permanant stone walls now interfere with its course.

The current at any point of the channel is moving, not only with an action due to the local influence of gravity, but also with the power accumulated at points higher up the stream. Of these two elements the. momenta is the conservative power, that which equalizes the depths of the water-ways and gives uniformity to the channel. It is this particular element of power which may be destroyed by bridges and open piling across the channel, which, although they suffer all the water to find its way through, do nevertheless produce much mischief. Among the railway bridges over the Charles River the utmost confusion is observable in the course of the tidal drift — its unity of movement is destroyed, it is local in character. To vessels towing through these bridges, the abrupt changes in the directions and velocities of the currents between the draws is a source of delay and vexation.

The tables and the diagrams appended to this report will be found to contain much that is suggestive and useful in unraveling the difficult questions concerning the tendencies of the harbor, but we have refrained from presenting some of our views because additional observations are requisite to furnish some of the intermediate steps in the arguments. We are convinced, from much experience in these studies, that all arguments and conclusions should rest upon numerical data obtained from careful observations and interpreted according to well founded doctrines of mechanics.

Besides the special localities, already referred to, we believe we have determined the part taken by the currents in the formation of Chelsea Flats, in the closing of Shirley Gut, the extension of Brewster Bar, and other prominent alterations which the various surveys of the harbor disclose. It is our purpose to tabulate all the forces at upwards of sixty points at which we have made systematic observations, and to illustrate our numerical data by diagrams, upon which the results will be represented geometrically. These tables and diagrams are very near their completion, the work of last season being already finished.

Of the field work, there yet remains something to be done. It is desirable that the curves of velocities at the principal bridges of the Charles River should be determined; and that examinations should be made of the gradual passing from sea to river waters as we ascend the streams — hydrometric observations designed to throw some light on the question of inland supply. When we have collected additional materials, we shall enter into fuller details, and embrace a wider field of inquiry.

When this physical survey was commenced, the importance of dividing the project into several seasons' work was especially set forth; and the reason assigned was, that our computations must keep pace in some degree with the field work, in order that in closing we might leave no point uncovered, but be possessed of the entire scheme of the harbor.

Although by economy of time and means we have been so fortunate as to make nearly one third more observations than projected, the advantage of much of this work will be lost unless the survey can be completed. The portion of the work upon which we have thus far reported, is but a small part of that which was accomplished; a full report can only be drawn up when we are able to fill in the details to which we have referred.

We cannot too strongly urge the importance of completing this work without delay. It would be impossible after the lapse of a very few years to recover the thread of our investigations and resume our studies, without going over much of the ground already traversed, which would add greatly to the expense. The harbor is undergoing a change of regimen by the action of artificial, as well as natural causes, and to obtain a comprehensive view of the intimate relations of phenomena from point to point, the observations at different stations should follow each other in as rapid succession as possible.

JOS. G. TOTTEN,
Bt. Brig.-Gen. U. S. A. Chief Engr.
A. D. BACHE,
Sup't. U. S. Coast Survey.
C. H. DAVIS,
Commander U. S. Navy.

No. 1.

CURRENTS OF BOSTON HARBOR,

From Observations made for United States Commissioners.

No. of Station.	Locality.	Current Turns.				Flood at max.		Ebb at max.		Duration of Current.		Duration of Slack.		Resultant of Scouring Forces for one Tidal Day.						Depth at mean low water.
		After Moon Souths.		After Tide.										Surface.						
		Flood to Ebb.	Ebb to Flood.	Flood to Ebb.	Ebb to Flood.	Vel.	Dir.	Vel.	Dir.	Fl'd.	Ebb.	Between Flood and Ebb.	Between Ebb and Flood.	Amt.	Dir.	Amt.	Dir.	Amt.	Dir.	
1	East of Boston Lower Light....	H. M. 12 45	H. M. 20 41	M. + 23	M. + 73	Miles. 0.32	Deg. Wly.	Miles. 0.53	Deg. 267	H. M. 5 26	H. M. 7 56	M. Indet	M. erm'e	1.31	Deg. 271	10ft. 1.90	Deg. 266	39ft. 1.61	Deg. 266	Ft. 89
2	Off Nantasket Beach	A	feeble	cur	rent	runs	to	the	N.W	19	hours	out	of 24.							
3	Between Graves and Nahant.....	12 12	18 58	+ 31	+ 60	0.30	50	0.35	236	5 28	6 46	8	62	Little	or no	scour	at	any	dp'h	81
4	Hypocrite Channel..............	11 33	17 26	+ 02	— 08	0.79	84	0.78	227	6 54	5 53	18	11	1.22	fl'd.	26ft. 1.17	fl'd.	75ft. 2.64	fl'd.	98
5	South of Brewster Bar...........	11 28	17 49	— 37	— 16	0.85	57	1.00	246	5 38	6 21	10	5	2.74	254					46
6	North of Brewster Bar...........	10 11	17 17	— 76	— 25	0.25	06	0.23	252	5 15	7 07	28	9	A fee	ble	south	ward	ly sco	ur.	33
7	Black Rock Channel..............	11 19	17 35	— 01	+ 04	1.02	32	1.20	216	6 06	6 16	03	8	0.40	219	11ft. 0.40	219	23ft. 0.40	219	23
8	South of Narrows Light........	7 51	14 47	—195	—162	0.28	105	0.27	260	5 45	6 56	5	25	No s	cour	at any	dept	h.		26½

9	East of George's Island.........					0.70	39	0.25	256	The	ebb is	unste	ady.	3.00	58	15ft. 3.50	40			25
10	Nantasket Roads................	11 23	17 46	+ 04	+ 19	1.00	70	1.25	238	6 06	6 23	20	10	2.21	244	9ft. 2.58	244	29ft. 2.65	244	62
11	East of Lovel's Island..........	10 55	16 49	— 24	— 45	0.40	52	0.28	176	6 33?	5 54	22	29	1.00	40					11½
12	Ram's Head Spit................	11 13	17 14	— 06	— 20	1.65	104	1.15	253	6 26	6 01	12	17	6.60	134					4½
13	Main Ship Chan'l N. of Geo.'s I..	10 30	17 30	— 12	0	1.65	96	1.57	275	5 27	7 00	0	0	2.30	274	15ft. 00		28ft. 0.40	274	41½
14	Bet. George's & Gallop's Islands	10 52	17 33	— 28	— 05	1.55	82	1.09	204	5 56	6 41	13	02	4.10	68	15ft. 5.40	69	38ft. 8.00	70	41
15	Main Ship Channel.............	The p	eriods	indeter	minate	0.25	120	0.35	97					0.60	97	11ft. 0.65	100	23ft. 1.00	125	28½
16	S. Chan'l Ent. to Broad Sound...	11 55	18 21	— 7	+ 14	1.46	71	1.89	242	5 52	6 26	1	7	2.30	245	28ft. 2.77	240	54ft. 2.30	245	66
17	N. Chan'l Ent. to Broad Sound...	12 14	18 05	+ 13	+ 4	1.40	9	1.13	200	5 25?	5 51	10	6	3.25	116	12ft. 2.29	116			16
18	Off Grover's Cliff................	Inde	termin	ate.		0.25	144	0.25	219					0.30	219					30
19	Bet. Nix's Mate and Gallop's I..	10 34	16 56	— 49	— 42	0.69	61	1.07	225	5 55	6 22	3	14	5.66	223					4
20	Bet. Nix's Mate and Long I.	11 34	17 09	+ 11	— 29	0.50	337	0.73	194	6 34	5 35	0	35	2.57	234					9
21	Broad Sound Channel...........	11 20	17 38	+ 13	+ 11	1.77	89	1.75	267	6 20	6 18	11	15							69
22	Shirley Gut.....................	10 37	16 52	— 42	— 39	1.86	61	1.40	237	6 09	6 15	2	8	2.37	59	11ft. 0.89	59	23ft. 1.11	232	27
23	Off Point Shirley................	Inde	termin	ate.		0.25	249	0.50	293	Inde	termi	nate.		3.82	283	25ft. 3.82	283			24
24	Near Point Shirley..............	11 07	17 34	— 01	— 34	0.63	224	0.45	267		6 27	0	5	5.92	258					31
25	Back or Western Way...........	11 27	18 09	+ 26	+ 48	0.34	121	0.78	289	5 54	6 42	13	18	4.00	290	15ft. 3.60	290			12
26	Bet. Thompson's and Spec. I'ds.	10 50	18 00	— 18	+ 37	0.22	146	0.40	304	5 15	7 10	29	43	1.70	310	11ft. 2.30	314			18
27	S. E. end Lower Middle..........	11 20	16 47	+ 5	— 41	0.40	75	0.39	250	6 34	5 27	17	25	0.41	199					9

TABLE No. 1. — CURRENTS OF BOSTON HARBOR (*continued*).

No. of Station.	LOCALITY.	Current Turns.				Flood at max.		Ebb at max.		Duration of Current.		Duration of Slack.		Resultant of Scouring Forces for one Tidal Day.						Depth at mean low water.
		After Moon Souths.		After Tide.		Vel.	Dir.	Vel.	Dir.	Fl'd.	Ebb.	Between Flood and Ebb.	Between Ebb and Flood.	Surface.						
		Flood to Ebb.	Ebb to Flood.	Flood to Ebb.	Ebb to Flood.									Amt.	Dir.	Amt.	Dir.	Amt.	Dir.	
		H. M.	H. M.	M.	M.	Miles.	Deg.	Miles.	Deg.	H. M.	H. M.	M.	M.		Deg.		Deg.		Deg.	Ft.
28	S. E. end Apple Island Flats....	13 09	18 50	+ 24	+ 32	0.44	218	0.45	15	7 14	5 41	0	13	1.26	273	13ft. 1.10	299			19
29	N. E. of Apple Island...........	11 32	18 44	— 29	+ 32	0.58	135	0.94	295	5 35	7 12	3	32	3.82	266	13ft. 3.82	266			21
30	N. W. of Apple Island	10 47	17 51	— 35	+ 17	0.35	79	0.39	248	5 21	7 04	22	18	0.75	245	15ft. 0.38	75			17
31	Lower Middle...................	Very	feeble	hori	zontal	mo	tion	at	any	stage	of	tide.								
32	Lower Middle...................	Very	feeble	hori	zontal	mo	tion	at	any	stage	of	tide.								3½
33	S. of Lower Middle	11 58	18 38	+ 12	+ 42	0.58	125	1.18	300	5 54	6 40	11	17	5.41	290					28½
34	W. end of Lower Middle........	10 34	17 27	— 51	— 03	0.19	140	0.73	254	6 21	6 53	45	28	2.87	247					10
35	N. of Lower Middle.............	11 37	17 01	+ 17	— 35	0.73	91	0.26	288	7 12	5 24	8	24	4.45	87					27
36	N. of Governor's Island.........	11 16	17 25	+ 08	+ 08	0.89	132	0.78	308	6 05	6 09	12	10							22
37	Off Dorchester Point............	11 42	17 43	+ 19	+ 48	0.24	169	0.34	331	5 30	6 01	23	30	0.30	334					4
38	On Upper Middle................	11 25	17 48	+ 13	+ 29	1.05	130	1.13	302	6 12	6 23	½	11	1.67	200	13ft. 4.10	143			21
39	N. W. of Upper Middle..........	11 22	18 16	— 14	+ 28	0.93	119	0.90	292	5 27	6 54	0	5	1.15	219					25
40	N. E. of Bird Island Beacon.....	10 56	18 14	— 35	+ 27	0.62	349	0.67	200	5 05	7 18	34	12	2.77	257			20ft. 3.49	274	40½

41	S. portion of South Boston Flats	11 00	17 37	— 27	+ 03	0.10	67	0.27	258	5 49	6 37	20	82	0.30	252	No s	cour	n'r bo	t'm.	4
42	W. of Slate Ledge	Uncer	tain.			0.12	86	0.35	302	Uncer	tain.			0.30	306					
43	N. W. of Slate Ledge	11 42	18 06	+ 31	+ 41	0.44	132	0.91	308	5 57	6 24	16	28	3.63	324	14ft. 2.29	330			
44	Bet. E. Boston and Bird I.	Inde	termi	nate.																9
45	South Boston Flats	Very	little	hori	zontal	move	ment	at	any	phase	of the	tide.								
46	Off Long Wharf	11 46	18 09	— 03	+ 10	0.28	152	0.48	348		6 23	2	25	2.02	2	13ft. 1.97	5			
47	Off East Boston	11 35	18 01	+ 02	+ 23	0.54	173	1.00	323	6 00	6 26	15	36	4.69	305			36ft. 0.46	149	
48	Fort Point Channel	11 17	17 36	+ 11	+ 15	0.84	21	0.86	199	6 01	6 19	18	05	1.54	44	9ft. 1.10	18			11
49	South Bay	10 50	17 36	— 24	+ 25	0.70	5	1.30	185	5 34	6 46	32	10	4.70	185					
50	Off Charlestown	12 52	18 51	— 6	+ 42	0.45	201	0.75	6	5 35	5 59	45	10							26
51	Mouth of Charles River	11 18	18 08	+ 12	+ 46	0.64	47	0.70	270	5 37	6 50	6	25							25½

No. 2.

COMPARATIVE VELOCITIES OF CURRENTS AT DIFFERENT DEPTHS.

Station 38. *On Upper Middle.*

OCTOBER 8 and 9, 1860.

Date. 1860.	Time.	Period of Current.	Velocity at Surface.	Azimuth.	Velocity at 6 feet.	Azimuth.	Velocity at 13 feet.	Azimuth.	Soundings.
	H. M.		Miles.	Deg.	Miles.	Deg.	Miles.	Deg.	Ft.
Oct. 8,	12 04	First hour of flood,	0.20	130			0.96	126	21½
"	14 04	Third hour of flood,	1.20	135	1.02	123	1.10	128	26
"	17 00	Last hour of flood,	0.25	159	0.30	134	0.75	138	30
"	21 05	Middle of ebb,	0.90	311	0.80	305	0.90	304	25
Oct. 9,	1 26	First hour of flood,	0.60	118	1.10	119	1.40	118	22
"	3 04	Third hour of flood,	1.05	126	1.13	125	1.09	126	27

No. 3.

COMPARATIVE VELOCITIES OF CURRENTS AT DIFFERENT DEPTHS.

Station 43. *N. W. of Slate Ledge.*

SEPTEMBER 18, 1860.

Date. 1860.	Time.	Period of Current.	Velocity of Surface.	Azimuth.	Velocity at 8 feet.	Azimuth.	Velocity at 25 feet.	Azimuth.	Soundings.
	H. M.		Miles.	Deg.	Miles.	Deg.	Miles.	Deg.	Ft.
Sept. 18,	13 04	Last hour of flood,	0.13	129	0.47	127	0.67	127	28
"	16 06	Third hour of ebb,	0.82	314	1.26	313	Depth 14 ft. 1.16	313	22
Sept. 19.	24 06	Fourth hour of fl'd,	0.40	131	1.10	120	1.00	133	24

No. 4.

COMPARATIVE VELOCITIES OF CURRENTS AT DIFFERENT DEPTHS.

Station 46. *Near Long Wharf.*

SEPTEMBER 24 and 25, 1860.

Date. 1860.	Time.	Period of Current.	Velocity at Surface.	Azimuth.	Velocity at feet.	Azimuth.	Velocity at 13 feet.	Azimuth.	Soundings.
	H. M.		Miles.	Deg.				Deg.	
Sept. 24,	10 06	Third hour of ebb,	0.42	356			0.42	336	
"	16 09	Third hour of flood,	0.35	153			0.39	153	
Sept. 25,	0 07	Fifth hour of ebb,	0.45	339			0.69	315	
"	7 08	Fourth hour of fl'd,	0.05				0.55	145	

No. 5.

COMPARATIVE VELOCITIES OF CURRENTS AT DIFFERENT DEPTHS.

Station 47. *Off East Boston.*

JULY 26, 1860.

Date. 1860.	Time.	Period of Current.	Velocity at Surface.	Azimuth.	Velocity at feet.	Azimuth.	Velocity at 36 feet.	Azimuth.	Soundings.
	H. M.		Miles.	Deg.	Miles.	Deg.	Miles.	Deg.	Ft.
July 26,	15 04	Third hour of flood,	0.45	151			0.75	154	44
"	16 03	Fourth hour of fl'd,	0.42	171			0.98	166	44
"	22 33	Fourth hour of ebb,	1.00	323			0.50	324	44

No. 6.

COMPARATIVE VELOCITIES OF CURRENTS AT DIFFERENT DEPTHS.

Station 48. *Fort Point Channel.*

SEPTEMBER 19 and 20, 1860.

Date. 1860.	Time.	Period of Current.	Velocity at Surface.	Azimuth.	Velocity at 9 feet.	Azimuth.	Velocity at feet.	Azimuth.	Soundings.
			Miles.	Deg	Miles.	Deg.			Ft.
Sept. 19,		Fourth hour of ebb,	0.70	206	1.30	205			13
"		Fourth hour of fl'd,	0.60	18	0.80	27			18
Sept. 20,		Second hour of fl'd,	0.75	18	1.00	18			15

returned to
the last date

y is incurred
the specified

y.

THE BORROWER WILL BE CHARGED AN OVERDUE FEE IF THIS BOOK IS NOT RETURNED TO THE LIBRARY ON OR BEFORE THE LAST DATE STAMPED BELOW. NON-RECEIPT OF OVERDUE NOTICES DOES NOT EXEMPT THE BORROWER FROM OVERDUE FEES.

CANCELLED
WIDENER
BOOK DUE
NOV 2 3 1982
7630360

WIDENER
BOOK DUE
MAY 2 1982
7477332
CANCELLED
JUN 9 1982
CANCELLED

CANCELLED
JAN 1 2 1989
JAN 1 3 1989
2804

WIDENER
BOOK DUE
JUN 1 9 1982
7523645

Eng 1018.62
Communications and reports in relat
Cabot Science 006791541
3 2044 092 005 800